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HEREDITARY TENDENCY TO FORM NERVE TUMORS

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The term multiple neurofibromatosis is applied to a rather rare condition characterized by the appearance of numerous sessile or pedunculated swellings or tumors of varying consistency and size. These may be present from birth, tend to grow larger and may even become confluent over a considerable area. Examination shows that they are fibrous tumors and frequently contain one or more nerve fibers or, if more deep seated, may be enlargements of the perineurium of nerve trunks. They are due to cell proliferations of the connective tissue sheaths of nerves.

The course of the disease is influenced by metabolic changes in the body. Thus pregnancy frequently stimulates growth of the small tumors which have been present from birth. In other cases even the changes of puberty are associated with the first marked development of the tumors. After various zymotic diseases, arsenical and lead poisoning, rapid growth of the tumors has been observed. The numbers of tumors may be very great, as many as 2000 or 4000. The tumors may be stimulated to grow by external mechanical agencies also, such as the irritation of a sword belt.

Associated with the tendency to form tumors is the production of pigmented spots or patches in the skin—of a café au lait color. Such patches when of small size may grow into colored moles or small tumors. On autopsy tumors are frequently found on the deeper lying nerves.

Multiple neurofibromatosis is a rare condition; it is found in only about 1 in 2000 cases that present themselves to medical clinics or private practitioners for skin diseases. Despite this there are many cases in the literature where 2 to 6 members of a family show some of the symptoms. The fact that only *blood* relatives are affected indicates that the disease is not a communicable one and it is equally certain that it is not induced by infection through

the placenta. The two sexes are nearly equally apt to be affected—of 243 affected persons 56.8% are males. The disease tends to recur without a break in the generations and is equally apt to come down the male and the female line. Consequently it looks as though the hereditary factor in neurofibromatosis is a dominant one. In each affected fraternity, indeed, about 50% of the individuals are affected, as is expected if it is a dominant trait. Actually 43.5% were found affected. In some cases, however, a generation is skipped—a result that can be explained on the hypothesis of occasional failure of dominance.

The symptoms of neurofibromatosis are very diverse. But inside of one family they are apt to be alike. This speaks strongly for the hypothesis of an inheritance factor. Similarly the location of the principal tumors is apt to be the same in one family, although it shows the greatest diversity in different families. Other multiple tumors are inherited in the same way as neurofibromata. Thus the tendency to form vascular tumors of the skin and mucous membranes has been shown by Osler (1901) and others since to be a dominant one. Polyadenomata are inherited similarly. Likewise the tendency to form pigmented patches in the skin (ephilides) was shown by Hammer to be a dominant trait. To this same group of heredity belong epidermolysis bullosa, angioneurotic oedema, and persistent hereditary oedema, also such skin diseases as psoriasis, porokeratosis and ichthyosis.

In not a few cases the removal of neurofibromata has been followed by malignant growths, at the same spot. It is plain that neurofibromata are in some way related to cancerous growths. The fact that neurofibromata have an inheritable basis strengthens the view that cancers in general have such a basis.

The complete paper will be published jointly with Dr. S. A. Preiser.

ARITHMETICAL THEORY OF CERTAIN HURWITZIAN CONTINUED FRACTIONS

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The following research is the outcome of the discovery, made some three years ago, that the denominators of the convergents of order $3n$, $3n-2$, and $3n-6$, as well as the numerator of the convergent of order $3n-3$ in the regular continued fraction which represents the base of Naperian logarithms, are all divisible by n. The convergents recur modulo n with a period of $6n$ when n is odd, and with a period of $3n$ when n is even.

To account for these curious theorems, and to place them in their proper setting, it was found necessary to study a more general type of continued fraction first investigated by Hurwitz.[1] The regular continued fraction for the Naperian base was discovered by Roger Cotes[2] to be $(2, 1, 2, 1, 1, 4, 1, 1, 6, 1, 1, 8, 1, 1, \ldots)$, or as we may write it $(2, 1, \overline{2n, 1, 1})$, $n = 1, 2, 3, \ldots$ The proof of the remarkable sequence of partial quotients was first given by Euler,[3] by means of the theory of the Riccati equation. Euler established a number of other interesting expansions, such as:

$$\sqrt{e} = (\overline{1, 1, 4n+1}),\ n = 0, 1, 2, 3, \ldots .$$

$$\sqrt[s]{e} = (\overline{1, s(2n+1)-1, 1}),\ n = 0, 1, 2, 3, \ldots .$$

$$\frac{\sqrt[s]{e}+1}{\sqrt[s]{e}-1} = (\overline{(4n+2)s}),\ n = 0, 1, 2, 3, \ldots .$$

The continued fractions studied by Hurwitz may be written in the form:

$$(q_1, q_2, q_3, \ldots q_r, \overline{\varphi_1(n), \varphi_2(n), \varphi_3(n), \ldots \varphi_k(n)}),\ n = 0, 1, 2, 3, \ldots .$$

where the 'irregular' partial quotients, $q_1, q_2, \ldots q_r$ are rational, and with the possible exception of q_1, all positive. The functions $\varphi_i(n)$ are rational integral functions whose degrees may, some or all, be zero. If the functions are all of degree zero, the fraction becomes an ordinary periodic continued fraction. The fractions discovered by Euler are seen to be Hurwitzian fractions where all the functions are of degree zero except one which is of the first degree. The general type of such a fraction with no irregular partial quotients is

$$(\overline{a_1, a_2, a_3, \ldots a_{k-1}, ma_k + b}),\ m = 0, 1, 2, \ldots .$$

and for such fractions I have been able to prove the congruences:

$$A_{2nk-1} - 1 \equiv B_{2nk} \equiv 0 \pmod{n},$$
$$A_{2nk} \equiv B_{2nk-1} \equiv (-1)^{nk-1} \pmod{n};$$

Where A_m/B_m is the mth convergent to the continued fraction, and n is any number prime to A_k, A_{k-1} and B_{k-1}; $a_1, a_2, a_3, \ldots a_{k-1}$ being positive or negative integers or zero; A_k, A_{k-1}, B_{k-1} positive or negative integers not zero.

The discussion is based on the following two theorems:

Theorem I. If A_m/B_m is the mth convergent of $(\overline{a_1, a_2, \ldots a_{k-1}, ma_k})$, $m = 1, 2, 3, \ldots$ and A'_m/B'_m is the mth convergent of $(\overline{a_{k-1}, a_{k-2}, \ldots a_2, a_1, -a_k m - 2M})$, $m = 1, 2, 3, \ldots$; where $M = (B_{k-1} + A_{k-2})/A_{k-1}$; where $a_1, a_2, a_3 \ldots a_{k-1}$, are positive or negative integers or zero, and where a_k, A_{k-1} are positive or negative integers, not zero, then:

$$A_{\rho k-1} = (-1)^{\rho-1} A'_{\rho k-1},$$
$$A_{\rho k} = (-1)^{\rho} (A'_{\rho k} + MA'_{\rho k-1})$$

for $\rho = 1, 2, 3, \ldots$.

Theorem II. With A_m/B_m defined as in Theorem I, and A''_m/B''_m defined as the $(m+1)$st convergent of

$$(K, \overline{a_{k-1}\, a_{k-2}, \ldots, a_2, a_1, L, a_{k-1}, a_{k-2}, \ldots, a_2, a_1, -a_k m - aM}),$$
$$m = 2, 3, 4, 5, \ldots,$$

where $K = (B_{k-1} - A_{k-2}) / A_{k-1}$
and $L = -a_k - 2\,(B^2_{k-1} + B_{k-2}\, A_{k-1}) / A_{k-1}\, B_{k-1}$;

$a_1, a_2, \ldots, a_k$, A_{k-1} and M as before, and B_{k-1} not zero, then:

$$B_{\rho k-1} = (-1)^{\rho-1} A''_{\rho k-1},$$
$$B_{\rho k} = (-1)^{\rho} (A''_{\rho k} + MA''_{\rho k-1})$$

for $\rho = 1, 2, 3, \ldots$.

These two theorems are proved by complete induction. The proof of each proceeds in an unusual and interesting way by assuming both equations of the theorem to hold for $\rho \leqq n$, then proving that the first of the two equations must be valid for $\rho = n + 1$, and then using this result to show that the second holds also for $\rho = n + 1$.

The three fractions considered in these two theorems are then discussed with respect to a modulus n prime to $2a_k$, A_{k-1} and B_{k-1}. It is possible to find an even value of m, say $m = 2\lambda$, which shall be less than $2n$, and which shall satisfy the congruence

$$a_k m + 2M \equiv 0 \pmod{n}$$

This value of m will provide a partial quotient in the second fraction of Theorem I, which shall be congruent to zero modulo n. The two continued fractions of this theorem are then seen to be inverse modulo n as far as this partial quotient. From the properties of inverse continued fractions, we have then $A_{2k\lambda-1} \equiv A'_{2k\lambda-1}$. But by Theorem I itself $A_{2k\lambda-1} = -A'_{2k\lambda-1}$ so that we derive $A_{2k\lambda-1} \equiv 0 \pmod{n}$.

It is possible, using only Theorem I, to show also that $A_{2k\lambda} \equiv B_{2k\lambda-1} \equiv (-1)^{\lambda(k+1)}$. To prove, however, that $B_{2k\lambda} \equiv M(-1)^{\lambda(k+1)}$ it is necessary to use Theorem II.

Certain interesting palindromic relations develop in the course of the proof, such as

$$A_{2k\lambda-(mk+1)} \equiv (-1)^{(k+1)(\lambda+m)} A_{mk-1} \pmod{n},$$

with a similar congruence in the B's.

With these values for the convergents of order $2k\lambda$ and $2k\lambda - 1$ it is possible to proceed to those of order $2kn$ and $2kn - 1$ with the results as noted above

$$A_{2nk} \equiv B_{2nk-1} \equiv (-1)^{nk-1} \pmod{n},$$
$$A_{2nk-1} \equiv B_{2nk} \equiv 0 \pmod{n},$$

and these last results are, without much difficulty, shown to be valid also for the more general fraction

$$\overline{(a_1, a_2, a_3 \ldots . a_{k-1}, a_k m + b)}, \quad m = 1, 2, 3, \ldots .$$

where n is prime to a_k, A_{k-1} and B_{k-1}. If we take the still more general fraction with irregular partial quotients:

$$\overline{(q_1, q_2, q_3 \ldots . q_r, a_1, a_2, a_3 \ldots . a_{k-1}, a_k m + b)}, \quad m = 1, 2, 3, \ldots .$$

the values given above for the convergents of order $2nk + r$ and $2nk + r - 1$ are no longer correct but must be replaced by the rth and $(r - 1)$st convergents of the fraction $(q_1, q_2, q_3 \ldots . q_r)$.

The above mentioned divisibility theorems concerning the Naperian base are easily derived from these general theorems. The special cases where n is not prime to $2a_k$ and to A_{k-1} and to B_{k-1} have been examined in detail. When A_k is divisible by n the fraction reduces modulo n to a purely periodic fraction of k partial quotients with no relations between them. The number of terms in the period of the convergents to such a fraction depends upon the discriminant D of the quadratic equation of which the fraction is one root. For a prime modulus p the period of the convergents is a divisor of $p + (D/p)$ where (D/p) is the symbol of Legendre.

For the case n a divisor of A_{k-1} (or B_{k-1}) the period of the convergents is a multiple of nke where e is the exponent to which A_k (or B_k) belongs modulo n. It is curious that for these special cases the period of the convergents does not seem to be definitely assignable as in the general case.

In this investigation we are concerned only with the successive values of the numerators and denominators of the convergents, and not at all with the existence or non-existence of a limiting value of the convergents. Certain of the fractions involved are closely related to those called 'semi-regular' whose convergence has been studied by Tietze,[4] and the rules which apply to semi-regular continued fractions may be easily modified to apply to them. The research here carried out is really an arithmetical study of the series of numbers which satisfy certain difference equations and, as Professor Birkhoff

has remarked, the theorems are thus related to the lesser Fermat theorem and to Wilson's theorem which are concerned respectively with the numbers which satisfy the difference equations $u_{x+1} = au_x$, and $u_{x+1} = xu_x$.

[1] Hurwitz, *Zurich, Vierteljahrsch. Natf. Ges.*, **41**, 1896, (34–64).

[2] Cotes, *Phil. Trans., London*, **29**, 1714, (5). (Reference in *Encyc. Sci. Math.*, Paris. Tome I, Vol. I, Fasc. 2, p. 169 note.)

[3] Euler, *Com. Acad. Petropolitanae*, **9**, 1737, (98–137).

[4] Tietze, *Math. Ann., Leipzig*, **70**, 1911, (236–265).

ON CLOSED CURVES DESCRIBED BY A SPHERICAL PENDULUM

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1. The geometrical aspect of the problem of closed curves in a spherical pendulum-motion has apparently never been fully discussed and it is the object of this note to present the results of an investigation of some of the geometric properties of these curves.

The differential equations of the motion are

$$\frac{d^2x}{dt^2} = -S\frac{x}{l}, \quad \frac{d^2y}{dt^2} = -S\frac{y}{l}, \quad \frac{d^2z}{dt^2} = -S\frac{z}{l} - g, \tag{1}$$

in which l is the length of the pendulum, S the variable reaction directed towards the origin (point of suspension). The velocity v of the pendulum-bob is, as is well known, given by $v^2 = h - 2gz$, in which h is a constant depending upon the initial conditions. For z as a function of t, we may obtain without difficulty

$$z = \frac{h}{6g} + \frac{2l^2}{g}\,p\,(t + w_2). \tag{2}$$

In this Weierstrassian p-function the one half-period w_1 is real; the other w_2 is pure imaginary. Putting $u = t + w_2$, let a and b be the arguments for which z assumes the values $-l$ and $+l$, respectively, and t_1 and t_2 the corresponding complex values of t. It is found that $a = i\alpha$, where α is real and positive, and $b = w_1 + i\beta$, with β equal to a fraction of $|w_2|$. The constant of integration may be determined such that $x = r_0$, $y = 0$, when $t = 0$. Under these conditions $\theta = \tan^{-1}(y/x)$ is defined by

$$e^{2i\theta} = \frac{\sigma(t+t_1)\,\sigma(t+t_2)}{\sigma(t-t_1)\,\sigma(t-t_2)} \cdot e^{-2i[\zeta_2(t_1)+\zeta_2(t_2)]} \tag{3}$$

From this is found

$$x = \phi(t) = \frac{r_0}{2} \frac{\sigma(t+t_1)\,\sigma(t+t_2)\,e^{-i[\zeta_2(t_1)+\zeta_2(t_2)]} + \sigma(t-t_1)\,\sigma(t-t_2)\,e^{i[\zeta_2(t_1)+\zeta_2(t_2)]}}{\sigma(t_1)\,\sigma(t_2)\,\sigma_2^2(t)}, \tag{4}$$

$$y = \chi(t) = -\frac{r_0 i}{2} \cdot \frac{\sigma(t+t_1)\,\sigma(t+t_2)\,e^{-i[\zeta_2(t_1)+\zeta_2(t_2)]} - \sigma(t-t_1)\,\sigma(t-t_2)\,e^{i[\zeta_2(t_1)+\zeta_2(t_2)]}}{\sigma(t_1)\,\sigma(t_2)\,\sigma_2^2(t)}. \tag{5}$$

These solutions may also be obtained from the differential equations.

$$\frac{d^2x}{dt^2} = \left[6\,p(t) - \frac{h}{2l^2}\right]x, \tag{6}$$

and a similar equation for y. (4) and (5) are uniform analytic functions of t, with ∞ as the only essential irregularity, and they assume real values for real values of t.

Increasing t by $2\,m_1\,w_1$, it is found that the motion will be periodic, when

$$2\,m_1\{\eta_1(a+b) - w_1[\xi(a) + \xi(b)]\} = 2ki\pi, \tag{7}$$

k being a positive integer. When t increases by $2\,w_1$, θ will increase by the amount

$$\Phi = -2i\{\eta_1(a+b) - w_1[\xi(a) + \xi(b)]\}, \tag{8}$$

so that in case of a periodic motion, from (7) and (8),

$$\Phi = 2k\pi/m_1. \tag{9}$$

The path described by the pendulum is now a closed curve intersecting every level between the lowest and highest position in $2\,m_1$ points and winding k times around the z-axis, before it closes.

Moreover a function-theoretic investigation of the periodic function

$$F(t) = \alpha.\phi(t) + \beta.\psi(t) + \gamma, \tag{10}$$

whose zeros determine the intersections of the straight line $\alpha x + \beta y + \gamma = 0$ with the horizontal projection of the curve (x, y), shows that *the curve is algebraic and passes through the circular (isotropic) points at infinity (i.e., its horizontal projection)*. From (3) follows that *the curve has an m_1-fold axial symmetry.*

2. In Greenhill's case[1] the pendulum-bob reaches (but does not go above) the horizontal plane of suspension with a non-vanishing horizontal velocity, and the parametric expressions for the horizontal projection may be written in the form:[2]

$$x = r_0[\cos(A+\pi)\, v.\ \mathrm{cn}\,(2Kv) - \mu \sin(A+\pi)\, v.\ \mathrm{sn}\,(2Kv)\ \mathrm{dn}\,(2Kv)\,], \quad (11)$$

$$y = r_0[\sin(A+\pi)\, v.\ \mathrm{cn}\,(2Kv) + \mu \cos(A+\pi)\, v.\ \mathrm{sn}\,(2Kv)\ \mathrm{dn}\,(2Kv)]. \quad (12)$$

$$\text{If } x' = r_0\ \mathrm{cn}\,(2Kv),\ y' = \mu r_0\ \mathrm{sn}\,(2Kv)\ \mathrm{dn}\,(2Kv),\ z' = a\ \mathrm{cn}^2\,(2Kv), \quad (13)$$

it is found that *the locus of the point $P'(x', y', z')$ is a quartic C_4 in space, and that P' is obtained by rotating the point $P\ (x, y, z)$ of the pendulum curve C about the z-axis through an angle $-(A+\pi)\,v$, i.e., through an angle negatively proportional to the time associated with P in the motion.*

Imposing upon (11) and (12) the same condition of periodicity, as in the general case, *the resulting curve in the xy-plane becomes a rational algebraic curve of order 2 k. The angle corresponding to the period 2 w_1 is, as before, $\Phi = 2k\pi/m_1$; k and m_1 being relatively prime. For a given odd m_1 there are $(m_1-1)/2$ curves of this type, for an even m_1, there are $(m_1-2)/2$ such curves. In both cases there are $m_1(k-1)$ real double points.*

When m_1 is odd there is just one curve among the set whose double-points are all real. Its degree is $2k = m_1 + 1$.

When m_1 is even, there is no such curve.

In case of an odd m_1 the polar equation of the curve has the form

$$\begin{aligned}&\rho^{2k} + a_1\rho^{2k-2} + a_2\rho^{2k-4} + \ldots\ldots + a_j\rho^2 + a + \\ &(b_1\rho^{2\lambda_1} + b_2\rho^{2\lambda_2} + \ldots\ldots + b_j\rho^2 + b)\ \rho^{m_1}\cos m_1\theta = 0,\end{aligned} \quad (14)$$

in which $a \neq 0$, $\lambda_1 > \lambda_2 > \lambda_3 > \ldots > 1$, and $2\lambda_1 + m_1 \leqq 2k - 1$. In cartesian coordinates (14) may be written in the form

$$\begin{aligned}&(x^2+y^2)^k + a_1(x^2+y^2)^{k-1} + a_2(x^2+y^2)^{k-2} + \ldots\ldots + a_j(x^2+y_2) + a + \\ &\{b_1(x^2+y^2)^{\lambda_1} + b_2(x^2+y^2)^{\lambda_2} + \ldots\ldots + b_j(x^2+y^2) + b\}. \quad (15)\end{aligned}$$

$$\left\{x^{m_1} - \binom{m_1}{2}x^{m_1-2}y^2 + \binom{m_1}{4}x^{m_1-4}y^4 + \ldots\ldots + (-1)^{\frac{m_1-1}{2}}\cdot xy^{m_1-1}\right\} = 0.$$

Transforming this curve by

$$x = \pm\sqrt{x''-y''^2-2y''-1}\,/\,y'',\ y = (y''+1)/y'',$$

or using isotropic coordinates, transformations which do not change the character of the isotropic points, and "placing the curve on the analytic triangle," the result is obtained that the isotropic points absorb together

$$(k-1)(2k-m_1-1) \quad (16)$$

double points, which when added to the $m_1(k-1)$ real double-points, gives $(k-1)(2k-1)$, i.e., the maximum number of double points which a curve of order $2k$ may have. Thus we have verified directly from the equation, that the curve is rational, as proved before. When the curve has all double points real, then its degree is $m_1 + 1 = 2k$, so that from (16) the number of

imaginary double points is clearly zero, which is another verification of previous results. (16) is also true when m_1 is even. Polar and cartesian equations for m_1 even may be established in a similar manner as in (14) and (15).

3. Examples.—When $m_1 = 3$, $2k = 4$, the polar and rational parametric equations of the curve[3] are

$$\rho^4 - R\rho^3 \cos 3\theta - \frac{27}{4}R^2\rho^2 + \frac{27}{4}R^4 = 0$$

$$x = \frac{t^4 - 12t^2 + 3}{4(1+t^2)^2},\ y = \frac{2t(3-5t^2)}{4(1+t^2)^2};\ (R = \tfrac{1}{4})$$

When $m_1 = 4$, $2k = 6$, cartesian and polar equations of the curve are

$$3(x^2+y^2)^3 - 24(x^4+y^4) - 32\,x^2y^2 + 39(x^2+y^2) - 18 = 0,$$
$$3\rho^6 - (2\cos 4\theta + 22)\rho^4 + 39\rho^2 - 18 = 0.$$

As m and k increase, the construction of the equations with numerical coefficients becomes increasingly difficult.[4]

[1] Greenhill, *Les Fonctions Elliptiques et leurs Applications*, chap. III.

[2] Tannery et Molk, *Eléments de la Théorie des Fonctions Elliptiques*, 4, pp. 176–192; Appell: *Traité de Mécanique Rationnelle*, 1, p. 494.

[3] This curve is known and was investigated by G. de Longchamps: *J. Math. Elémentaires*, 4, 1885, 269–277; also by H. Brocard: *J. Math. Spéciales*, (Ser. 3), 5, 1891, 56–64.

[4] A curve of this type may be symbolically denoted by $C_{2k}^{m_1}$. Tabulations of all curves, with their real and imaginary double points as far as C_{22}^{12} have been made, also actual graphs of C_4^3, C_4^6, C_6^5, C_8^5.

THE TAXONOMIC POSITION OF THE GENUS ACTINOMYCES

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To the genus Actinomyces are usually assigned a variety of peculiar and very minute filamentous organisms, widely distributed in nature, concerning the taxonomic relationship of which divergent views have been held. Most of the earlier medical writers, whose attention was centered on forms associated with human and animal diseases, placed the genus with the pleomorphic bacteria. Others recognized conidia in the clavate elements produced by one of these pathogenic forms, *Act. bovis*, within the animal body, and referred this parasite to the Fungi. These elements were later shown to represent degenerative structures; but as subsequent investigations on a number of species, including various saprophytic forms, as well as the common potato scab

organism and several pathogenic types clinically similar to *Act. bovis*, revealed decidedly fungoid characteristics, not only in the profusely branched condition of the vegetative thallus when grown in culture, but also in the production of an aerial mycelium and Oidium-like spores, the view that the genus is to be placed with the Hyphomycetes has continued to receive support.

According to another view which has gained quite wide acceptance, Actinomyces represents an intermediate group and a phylogenetic connection between the Bacteria and the Fungi. It is held that the genus originated either as the result of the development of bacterial forms possessing a tendency toward the branched condition, like the tubercle and the diphtheria organisms; or as the result of the reduction of hyphomycetous types, which, in their ultimate stages, yielded the much simpler true bacteria.

In order to determine the merits of these contending views, the writer subjected a large number of saprophytic species isolated from the soil, air, etc., as well as several virulent strains of the potato scab organism secured from Mr. M. Shapavalov, to morphological study. The results may be summarized as follows:

(1) The vegetative thallus of Actinomyces consists of a mycelium composed of profusely branching hyphae, the terminal growing portions of which are densely filled with protoplasm. Toward the center of the thallus, the vacuoles increase in size, and may be associated with the presence of metachromatic granules; the latter having nothing in common with bacterial endospores or 'micrococci,' for which they were mistaken by early observers.

(2) The vegetative mycelium attains an extent incomparably greater than the branching figures recorded for bacteria of the acid-fast group; and the hyphae lack the uniformity in diameter generally characteristic of the Schizomycetes.

(3) The aerial mycelium produced on suitable substrata by most species, occurs, usually, in the form of a mat of discrete fructifications; but in other species, these fructifications are frequently combined to form numerous peculiar erect Isaroid sporodochia.

(4) In any case, each individual fructification represents a well characterized sporogenous apparatus, consisting of a sterile axial filament bearing branches in an open racemose, or dense capitate arrangement. The primary branches may function directly as sporogenous hyphae, or may proliferate branches of the second and of higher orders; sporogenesis, in the latter case, being confined to the terminal elements, the hyphal portions below points of attachment of branches remaining sterile.

(5) Two tendencies in the development of fructifications are recognizable, one leading to an erect dendroidal type in which successively proliferated fertile elements undergo processes of sporogenesis in continuous sequence; and the other leading to a prostrate, racemose type, in which sporogenesis is delayed in the older branches until the younger branches have also attained their

final extension. The majority of species show these tendencies combined in different ways.

(6) The sporogenous hyphae of most species are coiled in peculiar spirals sometimes resembling the spores of the hyphomycetous genus Helicoön. These spirals exhibit pronounced specific characteristics in the number, diameter, and obliquity of their turns, and especially in the direction of rotation (whether dextrorse or sinistrorse).

(7) Sporogenesis, where it can be followed, begins at the tips of the fertile branches and proceeds basipetally. In the larger number of species the process involves the insertion of septa, which in certain cases, are relatively very massive, and in others, so thin as to be barely discernible. The disposition of these septa while the delimited spores undergo maturation processes, varies with the species: (1) they may remain more or less unaltered; (2) they may suffer a median split, the two resulting halves being then separated as the result of the longitudinal contraction of the young spores, leaving alternate portions of hyphal wall completely evacuated; (3) or they may first become considerably constricted and subsequently converted into non-stainable isthmuses connecting the mature spores. The apparent absence of septa in the sporogenous hyphae of other forms, is, perhaps, attributable to optical difficulties.

(8) Granules are readily differentiated in the spores of many species, which possess the staining properties and uniformity of size characteristic of nuclei; they generally occur singly, but in the larger spores of a few forms, two are often found occupying diagonally opposite positions.

(9) As in the vegetative thallus, metachromatic granules occur in the aerial mycelium, being very rarely found in spores or sporogeneous hyphae but becoming very abundant in degenerate sterile hyphae.

(10) The older axial filaments of some species show marked distensions, which, in extreme cases, result in figures simulating Leptomitus. These arise as local distensions at the points of attachment of the more extensive lateral sporogenous processes. Cuneate modifications of the sterile axial filaments below the origin of branches, also occur.

(11) Curious spherical structures appear regularly in some forms, both in the sterile axial hyphae, where they may contain either a median septum or a number of peripheral metachromatic granules, and in the sporogenous hyphae where they are associated with the regularly spaced septa.

(12) The spores germinate readily in suitable solutions, producing from one to four germ tubes, the approximate number being more or less characteristic of the species.

(13) Owing to the absence of any well defined bacterial characteristics, the writer is of the opinion that the view that Actinomyces represents a transition between the Hyphomycetes and the Schizomycetes, as well as the phylogenetic corollary based upon it, may safely be abandoned. If mere size is to be regarded as important, it would appear to be equally profitable to look

for bacterial affinities in some ascomycetous and sphaeropsidaceous forms, the hyphae of which are similarly very minute. It is doubtful whether far-reaching taxonomic generalizations can be based upon the 'acid-fast' staining reaction, especially as this reaction has not played a very important rôle in mycological research. There seems to be no adequate reason why the genus should not be classed, in an unqualified manner, with the Hyphomycetes, as a Mucedineous group with tendencies toward an erect Isaroid habit.

A more complete illustrated account will appear shortly in the *Botanical Gazette*.

STUDIES OF MAGNITUDES IN STAR CLUSTERS, VIII. A SUMMARY OF RESULTS BEARING ON THE STRUCTURE OF THE SIDEREAL UNIVERSE

By Harlow Shapley

Mount Wilson Solar Observatory, Carnegie Institution of Washington

Communicated by W. S. Adams, May 21, 1918

In the preceding communication of this series[1] methods were discussed for the determination of the relative distances of a considerable number of globular clusters. The methods have now been developed so as to give not only relative values but also fairly reliable absolute distances for all globular clusters, and for all variable stars of the Cepheid class for which periods and apparent magnitudes are known. A rather detailed summary of the procedure, its accuracy, and the results of a thorough application of the methods, has been given in the February issue of the *Publications of the Astronomical Society of the Pacific*. The present note will be confined to a synopsis of the more important results pertaining to the probable extent and arrangement of the sidereal system. The detailed discussion is appearing in a series of papers in the *Astrophysical Journal*, and will be separately published as *Contributions from the Mount Wilson Solar Observatory*, Nos. 151–157.

Extending to the globular clusters the work of Miss Leavitt, Hertzsprung, and Russell on the Cepheid variables of the Small Magellanic Cloud and of the galactic system, we have been able to establish beyond question the interdependence for these variables of absolute luminosity and period of light variation. By combining the apparent and absolute magnitudes, the distances and positions in space have been determined for about 140 Cepheid variables, most of which are much more distant than any objects for which parallaxes have been directly measured. Figure 1 shows their distribution.

The distances of globular clusters are of a different order of magnitude from those heretofore entering stellar investigations. Although the average naked-eye star is near as compared with many Cepheid variables, the most remote Cepheid now known is not so far away as the nearest globular cluster. The

available astronomical records contain 69 clusters that appear definitely to belong to the globular classification. Further work on very faint and distant objects will probably add a few to the present list, but within a distance of 100,000 light-years of the sun the survey appears to be complete. Keeping this limitation in mind, we may examine the collected data for signs of a general organization.

The apparent concentration of the globular systems to a southern region of the Milky Way has long been known. It now appears, upon closer investigation, that few if any typical globular clusters are to be found within 5° of the galactic plane; and, when actual positions in space are substituted for apparent positions, this suggested avoidance of the mid-galactic region reveals

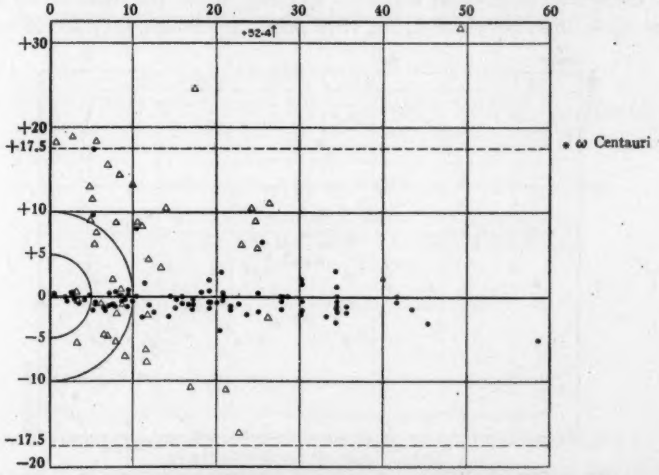


FIG. 1. DISTRIBUTION OF CEPHEID VARIABLES

The unit of distance is 100 parsecs. Ordinates are distances from the galactic plane; abscissae are projected distances in the plane. Open triangles and black dots designate, respectively, cluster-type variables and Cepheids with periods in excess of a day. The nearest globular cluster, ω Centauri, is just outside the boundary of the diagram on the right. RU Boötis, indicated by an arrow, is too far above the plane to fall within the figure. The semicircles, with radii of 500 and 1000 parsecs (π = 0".002 and 0".001), indicate how distant most of these variables are as compared with the average star of the tenth magnitude or brighter (π > 0".004, Kapteyn). Between the broken horizontal lines, ±1750 parsecs, lies the equatorial galactic region devoid of globular clusters.

itself as a total absence of compact clusters from the domains of space that appear to contain most of the known sidereal bodies.

The striking distribution of globular clusters in galactic longitude is well shown in the projection of their positions on the galactic plane in figure 2. Apparently the clusters themselves form a large flattened system, the center

of which, in the galactic plane, is between 60 and 70 thousand light-years distant in the general direction of the dense star clouds of Sagittarius and Scorpio.

The projection of the positions of clusters on a plane perpendicular to the Milky Way, and parallel to the direction of this center from the sun, is illustrated in figure 3. The shaded portion of the diagram indicates the equatorial region, toward which globular clusters crowd but in which they are not found; its thickness appears to be only three or four per cent of its extent along the galactic plane.

There can be little doubt that the galactic plane defined by the faint stars and by the Milky Way clouds is also a symmetrical and fundamental plane for the system of globular clusters. In other words, the distribution of clusters shows that, notwithstanding their great dimensions, they are subordinate

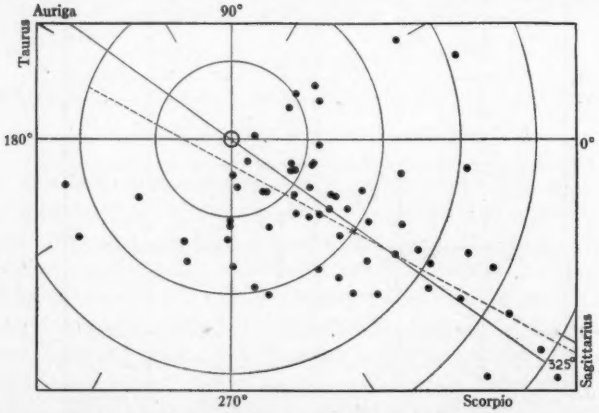


FIG. 2. THE SYSTEM OF GLOBULAR CLUSTERS PROJECTED ON THE PLANE OF THE GALAXY

The galactic longitude is indicated in the margin. The 'local system' is completely within the smallest circle, which has a radius of a thousand parsecs (3260 light-years). The larger circles, which are also heliocentric, have radii increasing by intervals of 10,000 parsecs. The dotted line indicates the suggested major axis of the system (if ellipsoidal), and the cross the adopted center. The dots are about five times the actual diameters of the clusters on this scale. Nine clusters more distant from the plane than 15,000 parsecs are not included in this diagram.

members of the far greater galactic system. Their arrangement and the relative densities of various parts of the Milky Way clouds strongly suggest that the whole sidereal system is roughly outlined by the positions of globular clusters, and that all known celestial objects—stars, nebulae, clusters—are members of a single unit.

The mean diameter of the proposed system appears to be at least 300,000 light-years; its most conspicuous feature is the equatorial segment, which apparently is thickly populated with stars throughout its whole extent. From

this viewpoint the Milky Way is mainly a phenomenon of depth; its extent, as seen from the sun, is something like three times as great in the direction of the center as in the opposite direction toward Auriga and Taurus. The testimony of the star frequencies in the Milky Way clouds does not disagree with the supposition of a remarkably eccentric position of the solar system.

Slipher's radial velocity observations of the brighter globular clusters[2] indicate that seven out of eight of those with high galactic latitudes are approaching the sun (and probably the equatorial segment) with such high velocities that, unless greatly retarded, they will have entered the dense stellar regions within an interval of time which appears to be short as compared with the probable history of a stellar system. The absence of such clusters from the

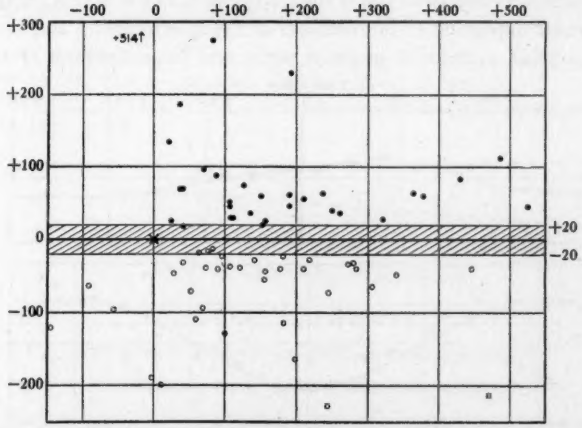


FIG. 3. PROJECTION OF THE POSITIONS OF GLOBULAR CLUSTERS ON A PLANE PERPENDICULAR TO THE GALAXY

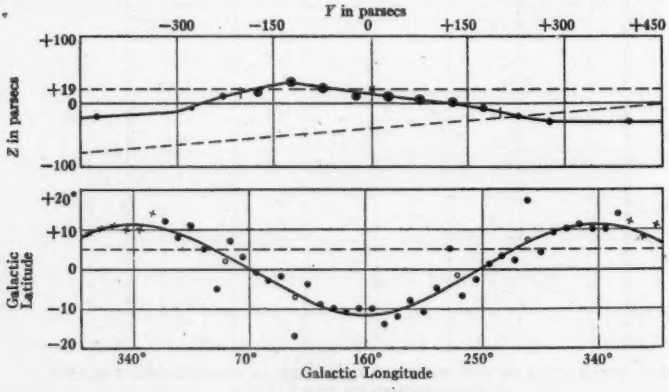
Illustrating (1) the absence of clusters from the mid-galactic region, (2) their symmetrical arrangement with respect to the Galaxy, (3) the eccentric position of the sun (the cross) with respect to the center of the system of clusters. The ordinates are distances from the galactic plane, $R \sin \beta$; the abscissae are projected distances in the direction of the center, $R \cos \beta \cos (\lambda - 325°)$. The unit of distance is 100 parsecs (326 light-years); each small square is 10,000 parsecs on a side. On this scale the actual diameter of each cluster is about one-fifth the diameter of the circles and dots. The cluster N.G.C. 4147 is outside the boundary of the diagram, as indicated by the arrow.

Galaxy thus becomes the more remarkable. The globular systems nearest the galactic plane are in general the least condensed. This result and the distribution of stars in certain open clusters suggest the possibility that upon approaching the galactic regions globular clusters may be disrupted and transformed into open galactic groups.

The galactic center as derived from the clusters is nearly at right angles to the direction of center obtained by Walkey and Charlier from statistical inves-

tigations of the brighter stars. The stars of spectral type B, according to Charlier,[3] form a flattened system of some 2000 light-years radius, which he identifies with the general stellar universe; the group is very small, however, as compared with the system now outlined by globular clusters, and we may assume instead that these B stars comprise a localized stellar organization.

To test further for the existence of a limited local cluster, situated far within the bounds of the equatorial segment and perhaps comparable in some respects with other open galactic groups, an investigation has been made of the galactic arrangement of the brighter stars. Details of this study are given in *Mount Wilson Contribution* No. 157. In brief, a verification is obtained of the presence of a local cluster, for which the following properties are indicated: (a) it contains very nearly all the B stars brighter than the seventh magnitude (the remainder appearing to be members of the intermingling and surrounding galactic field), a majority of the A stars, and large numbers of those of



FIGS. 4a AND 4b

Fig. 4*a*. (Above) Projection of the local cluster of B stars on a plane perpendicular to the Galaxy,—adapted from the data shown in Plate IV of Charlier's memoir. The inclination of the cluster's central plane to the Galaxy has been partially eliminated by Charlier. The projected center of the system of B stars, as derived by him, is at the origin of co-ordinates; the present work suggests that the central plane of the B stars is much nearer the sun (whose position is indicated by the cross) than Charlier supposed. The projection of the true galactic plane appears as a broken inclined line, and the distance of the sun and the local cluster north of it is to be noted. Short vertical lines across the curve show the limits of distance adopted for the solution represented by Fig 4*b*.

Fig. 4*b*. (Below.) Solution for the inclination of the local cluster to the galactic plane, based upon 400 stars of spectral-type B. Owing to the sun's position to the north, the central plane has a dip of 5°.

redder spectral types; (b) its central plane is not more than 30 light-years south of the sun and may be much nearer; on the other hand the true galactic plane, as defined by Cepheid variables, faint stars, and the galactic clouds, is approximately 175 light-years south of the center of the local cluster (fig. 4*a*); (c) the central plane, at least for the brighter stars, in inclined about 12° to

the galactic plane, with nodes in longitude 70° and 250° (figs. 4*a* and 4*b*); (d) the diameter is of the order of 2500 light-years.

The above results lead to a simple interpretation of star-streaming. The motion of an open cluster through the general star-fields of the equatorial segment must give rise to stellar drifts, and it is a natural assumption that the observed streaming in the neighborhood of the sun is wholly due to such a cause. According to this view, stars of Stream I belong to the large moving cluster surrounding the sun; those of Stream II belong to the galactic field. The motion of the cluster as a whole is in the galactic plane, nearly radial from the galactic center, and there is considerable evidence of internal motion within the cluster. In all the details examined, this hypothesis appears to be in agreement with the observed systematic motions of the stars.

[1] Shapley, H., these PROCEEDINGS, **3**, 1917, (479–484); *Mt. Wilson Communication*, No. 37.
[2] Slipher, V. M., *Popular Astronomy, Northfield, Minn.*, **26**, 1918, (8).
[3] Charlier, C. V. L., *Meddelanden fran Lunds Astro omiska Observatorium, Upsala*, (Ser. 2), No. 14, 1916, (1–108).

GLACIAL DEPRESSION AND POST-GLACIAL UPLIFT OF NORTHEASTERN AMERICA

BY H. L. FAIRCHILD

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Communicated by J. M. Clarke, June 4, 1918

The geophysical theory of isostacy is excellently illustrated by the up and down (diastrophic) movements of northeastern America in relation to glaciation. The amount and the area of land depression beneath the ice sheet, and the land uplift subsequent to the removal of the ice, is fairly proportionate to the thickness and extent of the latest ice cap.

The fact is evident that the area covered by the latest continental ice sheet, the Labrador (Quebec) glacier, stood much beneath its present altitude, relative to sea-level, when the ice melted off; and that the recent uplift has brought the land to its present position. The evidence of the uplift is abundant; many high-level beaches and sand-plains facing the open sea and extending far up the valleys in Canada, New England and New York, with the occurrence of abundant marine fossils hundreds of feet above the ocean. These facts have been recognized for quite a century, and many observations are recorded in the geologic literature of Canada and America. But up to the present time the full amount of submergence and the extent or limits of the drowned area have not been determined beyond dispute. The full amount of the down-and-up movement has nearly always been underestimated, because the conspicuous or more evident marine features are generally of inferior and later

water levels, while the initial or summit features are commonly weak and unobtrusive; or the latter lie so far inland and are so detached as to be unrecognized in their genesis and relationship, being commonly referred to glacial origin. However, the summit or initial level at any point is the critical and essential element in the problem.

Several years of study in the Hudson-Champlain, Ontario and Connecticut valleys has determined the position of the uplifted and tilted marine level.

In the Hudson-Champlain Valley the ancient estuary features rise from zero south of New York City to 740 feet on the north boundary of New York, and to over 800 feet on the north line of Vermont. Comparison of these features with similar phenomena in the Connecticut Valley gives the direction of the isobases (lines of equal uplift) as 20 degrees north of west by south of east; or 20 degrees east of north for the direction of steepest tilting. This figure is in close agreement with the determinations of Coleman, Goldthwait, Spencer and Taylor for the later deformation of the glacial lake shore lines in the Great Lakes area.

It has also been found that in the Ontario Basin the vertical interval between the tilted plane of Lake Iroquois and the plane of the sea-level waters (Gilbert Gulf) is 290 feet. Extension of the isobases of total uplift westward over the Ontario Basin gives very close accordance with the facts of observation in that field.

With the large area of New York State, Ontario basin and western New England as a well-determined base it has been possible to extend the study eastward over New England and eastern Canada. The result is shown in the accompanying map with at least close approximation to accuracy. On the small scale the map is somewhat generalized. The broken lines are entirely hypothetic only in the Mississippi Valley, where the land uplift may be more complicated in time and form. Except in the district west of Indiana and Michigan the map shows the rise of the continent subsequent to the removal of the latest ice sheet.

For Laborador and Newfoundland reliance is placed on the published data of R. A. Daly, with some help from unpublished figures of A. P. Coleman and J. B. Tyrrell.

Precaution is taken in this study to discriminate between features produced by sea-level waters and by glacial waters. In the inland areas, in order to avoid doubt or cavil as to glacial waters, the main dependance has been placed on the summit deltas of streams with southward flow, or with flow directed away from the receding ice margin. In the extended paper, noted below, will be found a description of field methods, and discussion of criteria for discriminating marine features.

The map shows apparently direct relation between the ice sheet and the diastrophic land movement. The area of uplift is the area of glaciation, and the amount of uplift is proportionate to the supposed thickness of the spreading ice cap. The map also shows the effect of land and sea on the flow and reach of the ice sheet. The ice deployed on the land but was inhibited by the sea; thus producing more rapid flow and steeper gradients along the radii toward the nearer sea shores. An independent ice cap is indicated for Newfoundland.

For the fuller discussion, in both methods and results; for description of the uplifted sea-level features in western New England, Maine, St. Lawrence and Ottawa valleys, Gaspé peninsula, New Brunswick, Nova Scotia, Labrador and Newfoundland; and for discussion of possible effects of any change in ocean level, the reader is referred to the formal paper in the *Bulletin of the Geological Society of America*, volume 29.

Former papers by the writer bearing on the subject of recent land uplift are as follows:

Pleistocene marine submergence of the Connecticut and Hudson Valleys, *Bull. Geol. Soc. Amer., New York*, **25**, 1914, (219–242).

Pleistocene uplift of New York and adjacent territory, *Ibid.*, **27**, 1916, (235–262).

Post-Glacial marine waters in Vermont, *Burlington, Rep. Vermont State Geologist for* 1915–16, 1917, (1–41).

Poat-Glacial submergence of Long Island, *Bull. Geol. Soc. Amer.* **28,** 1917, (279–309).
Post-Glacial features of the upper Hudson Valley, *N. Y. State Museum, Bull.*, 195, 1917.
Post-Glacial uplift of northeastern America *Bull. Geol. Soc. Amer.*, **29** (in press), 1918.

A BACTERIOLOGICAL STUDY OF THE SOIL OF LOGGERHEAD KEY, TORTUGAS, FLORIDA

By C. B. Lipman and D. D. Waynick

College of Agriculture, University of California

Communicated by A. G. Mayer, May 21, 1918

Inasmuch as the coarse calcareous sands of the islands off the Florida Coast, and of similar ones, represent very recent geological material, and since they, therefore, offer an opportunity of determining the early bacterial flora which establish themselves there, it was decided to carry out some studies on typical samples. Dr. A. G. Mayer, Director of the Marine Biological Laboratory of the Carnegie Institution, situated on Loggerhead Key, Tortugas, Florida, supplied us with the necessary samples for our study. Three large samples were collected, which answer to the following descriptions, for which we are indebted to Dr. Mayer:

No. 1. In region thickly covered with *Suriana maritima* bushes. About twenty feet north of stone wall built in 1868 and in a place where probably no man has trodden for 30 years or more. This sample is of an average depth of about 7 inches beneath the surface.

No. 2. Sand from the surface to 6 inches in depth from the northern end of Loggerhead Key. The region is barren of vegetation, no plants having ever grown within 200 feet of the place from which sample was taken. It is about 6 feet above high tide level on the crest of the island. Probably no man has walked here for 10 months previously.

No. 3. From an average depth of 15 inches below the surface in a place densely wooded with *Suriana maritima*. Same locality as Sample No. 1.

We thus had a soil and a subsoil sample from a part of the island in which large bushes (*Suriana maritima*) have established themselves as a permanent association. We also had a surface sample of very coarse, white, calcareous sand or grits, on which plants have never grown. It is to be noted, also, that there has been little or no opportunity for the contamination of these samples by the habitation or tread of man. The flora which now characterize the soil or sand material must take their origin either from the sea water, which now surrounds and which at one time probably covered them, or from winds carrying dust from older soils. The samples were collected by Dr. Mayer with the greatest care, large sterile bottles with cotton stoppers having been employed as containers. The cotton stoppers were doubly protected against contamination while in transit.

The studies carried out included counts of bacteria in the various samples, isolation and identification of pure cultures of the important bacteria and

fungi growing on mannite, beef, and synthetic agar, the determination of the soils ammonia and nitrate producing powers, of their nitrogen fixing powers, and of the isolation and study of the nitrogen fixing organisms found. In this preliminary note, we give merely a brief general statement anent our findings and reserve for another paper the more detailed discussion of the results obtained.

Bacterial Counts.—In the surface soil from the wooded part of the island, as many as a million organisms per gram were found when beef agar was used as a medium. Less than half as many organisms developed on synthetic agar and only about $\frac{1}{15}$ as many on mannite agar. In the subsoil from the same spot, there were approximately $\frac{1}{15}$ as many organisms developing on beef agar as on the surface soil and of synthetic agar the corresponding number was about $\frac{1}{10}$ that of the surface soil on beef agar and less than $\frac{1}{4}$ that on synthetic agar. The subsoil developed only one organism per gram on mannite agar.

In the highly calcareous sand free from vegetation, there were only about 8000 to 9000 organisms per gram of material on both beef and synthetic agar and only $\frac{1}{10}$ as many on mannite agar.

Nitrogen Transforming Powers of the Soils.—Both soil and subsoil from the wooded part of the island show powers of producing ammonia from dried blood nitrogen about equal to those of a poor sandy soil. The calcareous sand which, as has been observed above, contains relatively few organisms, possesses, nevertheless, a power of producing ammonia about three-quarters as great as that of the other soil material.

As regards nitrifying power, all the soils seem to be very feeble, if indeed they possess any such power appreciably. The amount of nitrate produced by the subsoil of the wooded part of the island seems to be above the limit of error, but, curiously enough, the surface soil produces no nitrate from sulphate of ammonia. The calcareous sand appears to produce a small quantity of nitrate from sulphate of ammonia, but the amount so formed may be within the limit of error. From the small amount of nitrogen which the soil itself contains, which in no case attains 0.01%, all of the samples seem to be powerless to produce nitrate. Dried blood in the quantities used seems to be no more satisfactory than sulphate of ammonia. These facts make possible some interesting speculation as to the nitrogen nutrition of the plants growing on the island, which we shall discuss in a future paper.

Nitrogen Fixing Powers and Organisms.—Perhaps the most interesting results obtained in these studies were those on the nitrogen fixing powers and organisms of the soil materials in question. All the samples gave characteristic Azotobacter films in mannite solution, the surface soil from the wooded land giving the heaviest film and the characteristic deep black pigment formation usually ascribed to *A. chroococcum*. The subsoil from the wooded land and the calcareous sand produced thin discontinuous films and little or no pigment. All the films, on microscopic examination, showed typical Azoto-

bacter cells. Judging, therefore, from the very small number of organisms which are found in the calcareous sand, Azotobacter, a nitrogen fixing organism, seems to be one of the earliest and one of the most numerous organisms. The nitrogen fixing power of the soils as measured by the ordinary laboratory test in solution cultures, in contrast with their nitrogen transforming powers, seem to be as vigorous as those of excellent soils. It is interesting, moreover, that the calcareous sand fixed about $\frac{5}{8}$ as much nitrogen in the tests mentioned as the surface soil from the wooded land and about $\frac{5}{8}$ as much as the subsoil of the same land.

Space does not permit a consideration here of some of the pure cultures of bacteria and fungi which were isolated from the soil samples studied. Three species of Actinomyces found appear to be new and as yet remain unnamed. Some of the common organisms of all soils were found, including bacteria, *Actinomyces*, and fungi. These will all be described in detail in a forthcoming paper, mention of which has already been made above.

It is a privilege to acknowledge again our obligation to Dr. A. G. Mayer for his kindness in sending the samples and for his interest in the work. We also express thanks to Dr. H. J. Conn and to Dr. S. A. Waksman for assisting in identification of a few cultures of bacteria and of *Actinomyces*, respectively.

AUTONOMOUS RESPONSES OF THE LABIAL PALPS OF ANODONTA[1]

By P. H. Cobb

Zoölogical Laboratory, Harvard University

Communicated by G. H. Parker, June 19, 1918

Although the ciliary responses of the labial palps of pelecypods have been much studied, the muscular movements of these organs have been entirely neglected. If one valve of an Anodonta is cautiously chipped off leaving the subjacent mantle-lobe intact and the animal resting in the opposite valve, the mantle-lobe thus freed may be folded back so as to expose the parts of the animal lying within the mantle chamber. In this way the labial palps in an almost undisturbed condition may be exposed and worked upon.

In such a preparation the external palp is to be seen resting on the internal one and both are quite flat. If, now, the external palp is touched with a blunt pointed instrument, particularly in its mid-dorsal region, the organ quickly buckles in on its dorsal edge close to its attachment to the mantle and soon after begins to curl from its free tip toward its attached base. On stimulating the internal palp, it responds as the external one does. Both palps in responding curl away from their opposed faces. The vigor of their response is apparently proportional to the stimulus. Grains of sand dropped on the outer face of the external palp affect it as a slight mechanical stimulus, which calls

forth some curling but almost no buckling. Currents of water when driven against the palp have very little effect as stimuli unless they are strong enough to indent the palp.

The palps are also open to chemical stimulation and the responses thus called forth are commonly much more pronounced than those due to mechanical stimulation. The chemical stimuli employed consisted in solutions of a number of common salts, acids, and alkalis, of such non-electrolytes as ethyl alcohol, sugar, urea, quinine and so forth, and of mixtures such as beef extract and the like. These were used in varying concentrations and to all, except sugar, a reaction much like that seen in vigorous mechanical stimulation was observed. In reaction to chemical stimulation, however, the palp showed a tendency to roll up tightly from the tip rather than simply to curl upon itself.

Electricity is also a stimulus for the palp. A faradic current just strong enough to be slightly stinging to the human tongue caused the palp to respond as to a mechanical stimulus. In efficiency the electrical stimulus was apparently midway between the mechanical and the chemical stimuli.

A jet of hot water that emerged from the container at 54°C. caused the palp to curl vigorously when it was directed on that organ in water at 16.5°C. A similar jet of water at the temperature of that in which the clam was, had no stimulating effect on the palp.

A beam of sunlight, or of strong electric light, or a sudden burst of light from flash-light powder had the remarkable property of causing the palp to curl. The response, which of course occurred well under water, though slower in its appearance than the responses to other forms of stimuli, followed so quickly on the stimulus that there was no doubt that the light, and not some accompanying disturbance, was the effective agency.

The surprising feature in all these responses is that they take place as effectively on a palp that has been freshly cut from a clam as on the palp intact. Careful comparative inspection of the reacting palps disclosed no obvious difference between the efficiency of these organs when normally attached to the clam and after they had been severed from it. On cutting a palp from a clam for experimental work, it is well to allow it to remain at least a quarter of an hour in quiet water before subjecting it to stimulation. Such a palp is responsive for about an hour and a half after removal. This condition shows that the palp contains within itself the neuromuscular organization necessary for all the responses described in this paper, and that it, therefore, possesses an autonomy even more complete than that of the vertebrate heart and comparable with what is shown by the tentacle of an actinian.

It is intended to continue the line of investigations suggested by these studies and to extend them to the histology of the parts concerned.

[1] Contributions from the Zoölogical Laboratory of the Museum of Comparative Zoölogy at Harvard College. No. 311.

THE DEPTH OF THE EFFECTIVE PLANE IN X-RAY CRYSTAL PENETRATION

By F. C. Blake,

Department of Physics, Ohio State University

Communicated by E. H. Hall, May 25, 1918

In determining the value of 'h' by means of X-rays Blake and Duane[1] (p. 636) found out by experiment that the 'depth of the effective plane' was 0.203 mm. for the case of calcite, using X-rays of a wave-length 0.454 Ä. An attempt is made in this note to explain this theoretically.

Call μ the coefficient of true absorption and r the reflection coefficient. Suppose a parallel beam of X-rays strikes the crystal face at glancing angle θ. Then if A_0 is the amplitude of the primary beam the total effect at the ionization chamber is the sum of the various reflections from all those planes of atoms that are able for any reason to play a part at the ionization chamber. Call the last plane of atoms that is thus effective the mth plane. Figure 1 will render the situation clear. Let AB–IJ represent the parallel beam of X-rays as determined by the slit-width s. The reflected beam bdf, for instance, is the sum of the various reflections at b, d, and f. Ray AB suffers partial reflection at A and arrives at a with amplitude $A_0 l^{-\mu d \csc\theta}$ where it again suffers reflection. The reflected part has the amplitude $rA_0 l^{-\mu d \csc\theta}$ at a and by the time it gets to c its amplitude has been reduced to $rA_0 l^{-2\mu d \csc\theta}$. Thus the total amplitude along any reflected ray bdf situated a distance x away from the first reflected ray AI is

$$rA_0\left(1+e^{-2\mu d\csc\theta}+e^{-4\mu d\csc\theta}+\ldots+e^{-2n\mu d\csc\theta}\right), \text{ in which } n=\frac{x}{2d\cos\theta}.$$

This gives for the amplitude of the ray bf,

$$rA_0\frac{1-e^{-2(n+1)\mu d\csc\theta}}{1-e^{-2\mu d\csc\theta}}, \text{ reducing to } rA_0\frac{1-e^{-\frac{\mu x}{\sin\theta\cos\theta}}}{2\mu d\csc\theta},$$

very approximately.

Call D_1 the mean depth of the ray bdf. Then

$$rA_0\frac{1-e^{-\frac{\mu x}{\sin\theta\cos\theta}}}{2\mu d\csc\theta}=nrA_0e^{-2\mu D_1\csc\theta}.$$

Solving for D_1 we have

$$D_1=\frac{\sin\theta}{2\mu}\log_e\frac{\mu x}{\sin\theta\cos\theta\left(1-e^{-\frac{\mu x}{\sin\theta\cos\theta}}\right)} \qquad (1)$$

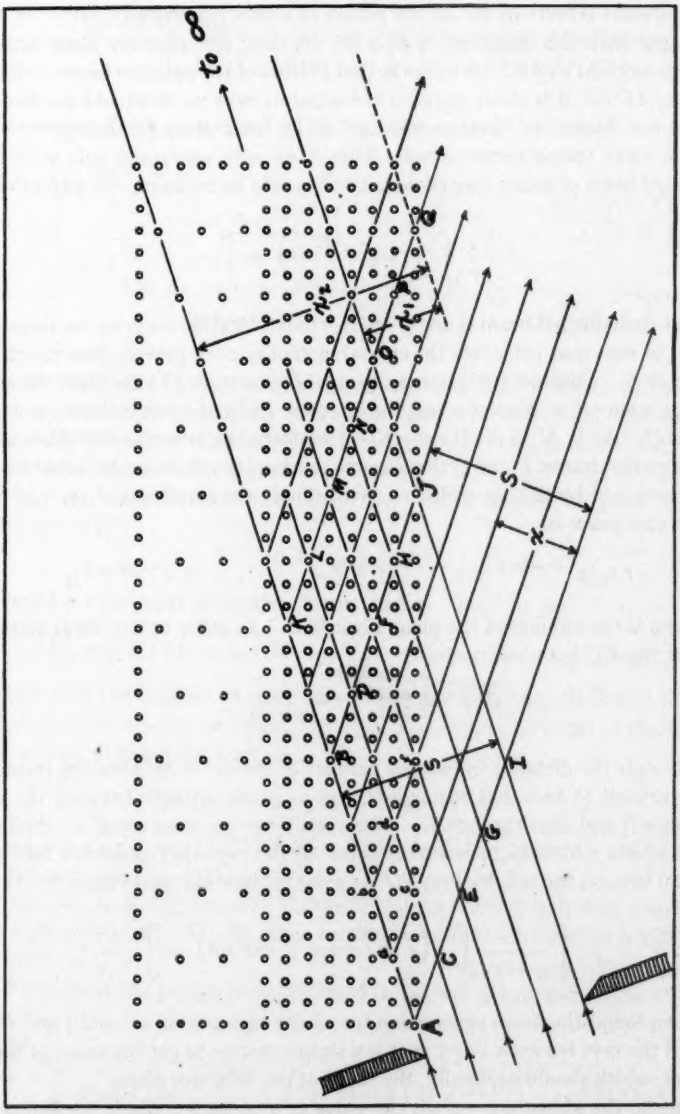

FIG. 1.

Now the 'effective plane' was defined by Blake and Duane[1] (p. 632) as that plane at which if reflection for all the rays occurred at *that* plane *only* the effect at the ionization chamber would be the same as actually does occur due to

the different reflections for all the planes of atoms playing any part. In accordance with this definition, if D is the depth of the 'effective plane' and if for the moment we limit ourselves to that portion of the reflected beam of width s, viz., AI–BJ, it is clear, since for the separate rays we must add not amplitudes but intensities, that we must get D by integrating D_1 throughout the region s and taking mean values. Thus if we were concerned only with the reflected beam of width s we could get D from (1) by replacing the parenthesis by

$$\left[\frac{1}{s}\int_0^s \left(1-e^{-\frac{\mu x}{\sin\theta\cos\theta}}\right)^2 dx\right]^{\frac{1}{2}}.$$

But the reflected beam is not of width s only. Rather must we consider the effect of rays that penetrate the crystal to depths much greater than the plane through B. Consider for instance the ray AB penetrating to the plane through K say, where it is reflected along the direction KQ and emerges from the crystal at Q. At L, M, N, O the ray KQ is reinforced by reflections in phase with one another, but at P and Q there are no reinforcements since the initial beam is determined by the slit width s. Accordingly the amplitude of the ray KQ upon emergence is

$$rA_0\left(e^{-2n\mu d\csc\theta}+e^{-2\cdot n-1)\,\mu d\csc\theta}+\ .\ .\ .\ .\ +e^{-2q\mu d\csc\theta}\right),$$

where q is the number of the plane through O. In other words the amplitude of the ray KQ upon emergence is

$$e^{-\frac{\mu x_1}{\sin\theta\cos\theta}}-e^{-\frac{\mu x_2}{\sin\theta\cos\theta}},$$

where x_1 is the distance (measured parallel to the slit s) between the incident ray through Q and that through O, and x_2 is the distance between the ray through Q and that through K. Necessarily x_2-x_1 must equal s. Accordingly to get our mean penetration D for all the rays that penetrate into the crystal beyond the reflected ray BJ we must replace the parenthesis in (1) by

$$\left[\frac{1}{x_2-x_1}\int_s^\infty \left(e^{-\frac{\mu x_1}{\sin\theta\cos\theta}}-e^{-\frac{\mu x_2}{\sin\theta\cos\theta}}\right)^2 dx\right]^{\frac{1}{2}}.$$

Having found the mean penetration for all the rays between 0 and s and that for all the rays between s and ∞ it is a simple matter to get the mean of these means, which should be, finally, the depth of the 'effective plane.'

Now in the above expressions the value of μ is the amplitude coefficient of absorption while what is experimentally measured is the intensity coefficient of absorption. If we accordingly replace 2μ in the above expression by μ we have as our expressions for the depth of the effective plane the following:

For the X-rays contained in the triangle ABJ,

$$D' = \frac{\sin\theta}{\mu}\log_e \frac{\mu s}{2\sin\theta\cos\theta\left[\frac{1}{s}\int_0^s \left(1-e^{-\frac{\mu x}{2\sin\theta\cos\theta}}\right)^2 dx\right]^{\frac{1}{2}}}; \qquad (2)$$

and for the X-rays contained in the parallelogram $BK \infty \infty OJB$,

$$D'' = \frac{\sin\theta}{\mu}\log_e \frac{\mu s}{2\sin\theta\cos\theta\left[\frac{1}{s}\int_s^\infty \left(e^{-\frac{\mu x}{2\sin\theta\cos\theta}} - e^{-\frac{\mu(x+s)}{2\sin\theta\cos\theta}}\right)^2 dx\right]^{\frac{1}{2}}}$$

$$= \frac{\sin\theta}{\mu}\log_e \frac{\mu s}{2\sin\theta\cos\theta\left(1-e^{-\frac{\mu s}{2\sin\theta\cos\theta}}\right)\left[\frac{1}{s}\int_s^\infty e^{-\frac{\mu x}{\sin\theta\cos\theta}}\cdot dx\right]^{\frac{1}{2}}}. \qquad (3)$$

Now Blake and Duane, in determining the maximum positions of the ionization chamber corresponding to a given value of θ had in one case made θ equal to 4°18′, which corresponded to a wave-length λ equal to 0.454 Å, Using Duane's formula for the absorption, viz., $\mu/\rho_{Al} = 14.9\,\lambda^3$ we get $\mu/\rho_{Al} = 1.394$. Applying Bragg's formula for the atomic absorption coefficient, a, say, we have

$$a \equiv \mu\omega/\xi = kN^4,$$

where k is a constant and ω the atomic weight. Thus we get

$$a_{Al} = 37.79\,a^{-1},\ A_{Ca} = 211.7\ A^{-1},\ a_C = 1.71\ A^{-1},\ a_O = 16.26\ A^{-1},$$

where A is the number of molecules in a gram molecule, viz. 6.062×10^{23}. If now we assume the molecular absorption, m say, to be equal to the sum of the atomic absorptions, we have

$$m_{CaCO_3} = a_{Ca} + a_C + 3a_O = 229.67\ A^{-1},$$

whence $\mu : \rho_{CaCO_3} = 229.67 : 100.07 = 2.295$; and if we take ρ for calcite to be 2.712, μ comes but equal to 6.22.

Now W. L. Bragg has shown[2] that for calcite there is only half a molecule to each elementary cell. In other words, the value of μ we require is $6.22 : \sqrt[5]{2} = 4.94$.

Performing the integrations indicated in (2) and (3) we get

$$D' = \frac{\sin\theta}{\mu}\log_e \frac{\mu s}{2\sin\theta\cos\theta\left[\frac{1}{\mu s}\left\{\mu s + \sin\theta\cos\theta\left(4e^{-\frac{\mu s}{2\sin\theta\cos\theta}} - e^{-\frac{\mu s}{\sin\theta\cos\theta}} - 3\right)\right\}\right]^{\frac{1}{2}}} \qquad (4)$$

and

$$D'' = \frac{\sin\theta}{\mu}\log_e\left[\left(\frac{\mu s}{\sin\theta\cos\theta}\right)^{3/2}\frac{1}{\left(1-e^{-\frac{\mu s}{2\sin\theta\cos\theta}}\right)e^{-\frac{\mu s}{2\sin\theta\cos\theta}}}\right].$$

Now in the work of Blake and Duane s was 0.040 cm. Taking $\mu = 4.94$ and $\theta = 4°18'$, D' comes out 0.150 mm.; and D'', 0.363 mm.

If we plot the relative intensity, viz.

$$\left(1 - e^{-\frac{-\mu x}{2 \sin\theta \cos\theta}}\right)^2,$$

against x, we get Curve I of figure 2 for values of x less than 0.04 cm. For values of x greater than 0.04 cm. the relative intensity is

$$\left(e^{-\frac{\mu x}{2 \sin\theta \cos\theta}} - e^{-\frac{\mu (x+s)}{\sin\theta \cos\theta}}\right)^2,$$

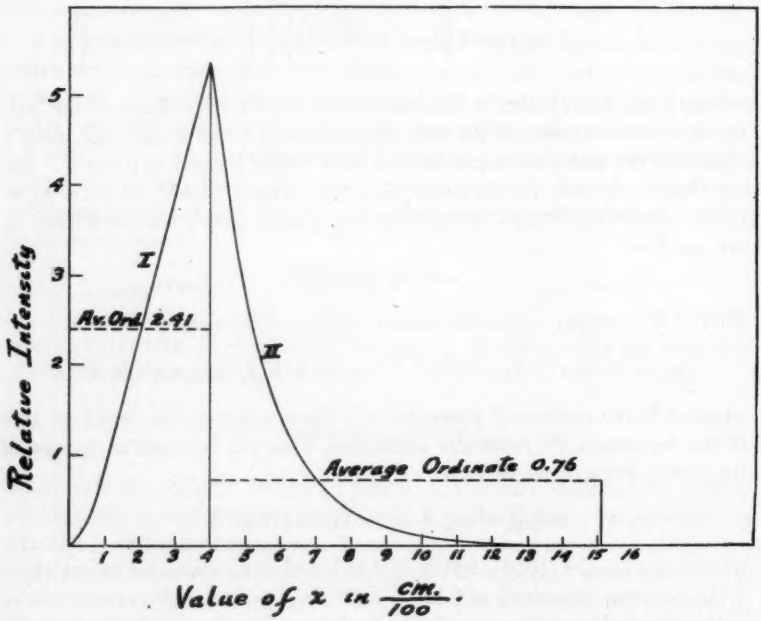

FIG. 2.

and plotting this against x, we get Curve II of figure 2. Measured carefully with a planimeter the average ordinate for I is 2.41 and for II it is 0.76. Finally therefore we have as the depth of the effective plane

$$D = \frac{2.41\, D' + 0.76\, D''}{3.17} = 0.201 \text{ mm.}$$

Blake and Duane found D experimentally to be 0.203 mm. Thus the agreement is all that can be expected.

In figure 1, for simplicity sake the writer has assumed the space lattice for calcite to be cubical; as a matter of fact it is rhombohedral. Blake and Duane

pointed out[3] that, when crystal penetration is properly corrected for, the curve of atomic number versus square root of frequency is *almost* a straight line, their own values falling more nearly on a straight line than either those of Moseley or de Broglie. As a matter of fact it is manifest that the effective reflected ray for a crystal like calcite is along such a direction as to make the measured angle of reflection proportionately too large for the higher frequencies. In other words as the atomic number increases the measured frequency is proportionately greater than it should be. This possibly accounts for the fact that the curve in figure 3 of Blake and Duane's paper is convex downward toward the axis of atomic numbers. It would seem that a test of this reasoning could be made by repeating the work of Blake and Duane using a crystal with a cubic lattice but one whose faces are as good as those of calcite (rock salt is notoriously bad), care being used of course to correct for crystal penetration, or to eliminate the effect of such penetration by using a very narrow incident beam and having the ionization chamber slit very wide (the arrangement shown in figure 1, first used by Duane and Hunt[4]).

[1] *Physic. Rev. Ithaca*, **10**, 1917, (624–637).
[2] *Proc. Roy. Soc.*, (A), **89**, 1914, (468).
[3] *Physic. Rev. Ithaca*, **10**, 1917, (703).
[4] *Ibid.*, August, 1915, p. 166.

THE MYODOME AND TRIGEMINO-FACIALIS CHAMBER OF FISHES AND THE CORRESPONDING CAVITIES IN HIGHER VERTEBRATES

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A functional myodome is found only in fishes, and even among them it is limited, in the specimens I have examined, to Amia and the non-siluroid Teleostei.

The myodome is always separated from the cavum cerebrale cranii by either membrane (dura mater), cartilage or bone, and the separating wall is in part spinal and in part prespinal in position. A depression in the prespinal portion lodges the hypophysis, or both the hypophysis and saccus vasculosus, and this part of the wall never undergoes either chondrification or ossification, a more or less developed pituitary sac always projecting into the myodome.

The myodome is found in its most complete form in the Teleostei, and there consists of dorsal and ventral compartments, which are usually separated from each other by membrane only, but that membrane, the horizontal myodomic membrane, is capable of either chondrification or ossification. The dorsal

compartment lodges the hind ends of the musculi recti externi, and is always traversed by a cross-commissural venous vessel formed by the pituitary veins. The ventral compartment lodges the hind ends of the musculi recti interni, and is traversed by the internal carotid and efferent pseudobranchial arte ies and the palatine branches of the nervi faciales.

The parasphenoid forms the floor of the ventral compartment of the myodome, and whenever the horizontal myodomic membrane undergoes ossification, the bone so formed forms part of the parasphenoid. This bone is thus certainly, in certain fishes, in part of axial origin, and not simply a dermal bone that has gradually sunk inward to its actual position.

In the Siluridae (Ameiurus) there is apparently a much reduced, but non-functional, dorsal myodomic compartment, but no ventral compartment, that portion of the parasphenoid that lies in the proötic region being developed in what corresponds to the horizontal myodomic membrane of others of the Teleostei.

In Amia the myodome corresponds to the dorsal compartment only of the teleostean myodome, and a strictly similar, but non-functional, myodomic cavity is found in Lepidosteus and Polypterus. The ventral compartment of the teleostean myodome is represented, in each of these three fishes, by a canal, on either side of the head, that is traversed by the internal carotid artery, and that corresponds to the canalis parabasalis of Gaupp's[1] descriptions of higher vertebrates.

The myodomic cavity is limited, in the Holostei and Crossopterygii, to the proötic region, and is there in part subspinal and in part prespinal and subpituitary in position. In the non-siluroid Teleostei examined, the dorsal compartment of the myodome is always more or less pro'onged posteriorly into the basioccipital region, and the ventral compartment is frequently so prolonged.

The posterior part of the basioccipital portion of the myodome lies between ventro-lateral vertebral processes that are quite certainly the homologues of the haemal arches of the tail. In Hyodon, this part of the myodome is an open groove and lodges the anterior portion of the median dorsal aorta. In the Cyprinidae, part of this groove has become enclosed to form a short canal, which is traversed by the median dorsal aorta, the enclosing bone forming the pharyngeal process.

The conditions in these fishes thus leads inevitably to the assumption that the entire dorsal myodomic cavity is a subvertebral canal similar to the haemal canal in the tail, and that the dorsal aorta has been excluded from it because of the formation of a circulus cephalicus. What the primary relations of the hypophysis and pituitary veins to this preëxisting canal were, is problematical, but they became lodged in its anterior portion and so gave rise to the conditions actually found in Lepidosteus and Polypterus. The musculi recti externi then secondarily invaded this space by traversing the foramina for the

pituitary veins, the other recti muscles retaining their insertions on the external surface of the preclinoid wall, and so gave rise to the conditions found in Amia. The conditions found in the non-siluroid Teleostei then arose as a result of the resorption of the cartilage that, in Amia, forms the preclinoid wall, the pedicel of the alisphenoid, and those ventral portions of the b sicapsular commissures that form the lateral walls of the subpituitary portion of the myodome. Because of the resorption of the preclinoid wall, and its replacement by membrane, the musculi recti interni, which in Amia have their points of insertion on either lateral edge of that wall, have first sought firmer attachment on the dorsal surface of the parasphenoid, and have then later pushed posteriorly in the open ends of the persisting portions of the canales parabasales. The fusion of these two canals with each other then formed a ventral myodomic compartment, which is, in early embryos, separated from the dorsal and primary compartment by membrane only; but this membrane may undergo either partial chondrification (Hyodon), or ossification (Gasterosteus) the bone, in the latter case, forming a transverse and inclined ridge on the dorsal surface of the parasphenoid. The membranes resulting from the resorption of the preclinoid wall were then pressed together in the median line by the recti interni, and form a median vertical myodomic membrane, which encloses the internal carotid arteries in a membranous canal that is the homologue of the cartilaginous canals of Amia. The efferent pseudobranchial arteries, pressed downward by the recti interni, lost their connections with the internal carotids and acquired a cross-commissural connection with each other. The membrane resulting from the resorption of the anterior portions of the basicapsular commissures of either side ossified as part of the ascending process of the parasphenoid, and the tissues resulting from the resorption of the pedicel of the alisphenoid ossified, in certain fishes (Cottus, Gasterosteus), to form an anterior portion of that same process.

In the Selachii the myodomic cavities of the Holostei and Teleostei are represented either by canals in the basis cranii that are traversed by the pituitary veins and the internal carotid and efferent pseudobranchial arteries, or by a posterior and deeper portion of the large pituitary fossa of the chondrocranium that is shut off from the cavum cerebrale cranii by the dura mater, and is traversed by the pituitary veins and the internal carotid arteries.

In embryos of Ceratodus there is a subpituitary space, traversed by the pituitary veins, that corresponds to the dorsal compartment of the teleostean-myodome, and the internal carotid canals of Amia have been added to it. This fusion of these canals with the dorsal myodomic cavity is due either to the resorption of the cartilage that separates them in Amia, or to a shifting posteriorly of both the hypophysis and the internal carotides from a position between the hind ends of the trabeculae to one between the so-called anterior prolongations of the parachordals.

In the Amphibia the basis cranii apparently corresponds to the roof, and not the floor, of the dorsal myodomic cavity of Amia and the Teleostei. The fenestra hypophyseos of these animals is, then, the homologue of the pituitary opening of the brain case of fishes.

In the Reptilia and Mammalia a dorsal myodomic cavity is found that is similar to that in Ceratodus. In man it is represented in the cavernous and intercavernous sinuses, and the venous vessels that traverse those sinuses are the homologues of the pituitary veins of fishes.

The cartilago acrochordalis of Sonies's[2] and Noordenbos's[3] descriptions of birds and mammals, respectively, is the homologue of the cartilaginous prootic bridge of embryos of fishes. The open space between this cartilage, or bridge, and the anterior end of the parachordal plate is the fenestra basicranialis posterior properly so called. This fenestra is a perforation of the roof of the myodomic cavity, and hence is not the homologue of the so-called fenestra basicranialis posterior of embryos of fishes, which fenestra is a perforation of the floor of that cavity. This latter fenestra of embryos of fishes is the homologue of the fenestra hypophyseos of birds and mammals, the so-called anterior prolongations of the parachordals of fishes being the homologues of the polar cartilages of birds and mammals.

In certain of the Selachii there is an acustico-trigemino-facialis recess, and there may be certain canals in the cranial wall that are traversed by the vena jugularis and the external carotid artery.

In Amia the trigemino-facialis portion of this recess has fused with the canals for the vena jugularis and the external carotid artery to form a trigemino-facialis chamber, this chamber has become continuous ventrally with the myodome, and the large chamber so formed has been prolonged anteriorly by a space enclosed between the pedicel of the alisphenoid and the primitive side wall of the neurocranium. The foramina for the pituitary vein and the nervi oculomotorius and trochlearis open into this anterior prolongation of the chamber, and, through its orbital opening, into the orbit. The vena jugularis traverses this orbital opening to enter and traverse the trigemino-facialis chamber; the musculus rectus externus traverses it to enter the myodome; and the nervus profundus traverses it to join the ganglion or root of the nervus trigeminus. The nervus trigeminus and the external carotid artery issue from the trigemino-facialis chamber posterior to the pedicel of the alisphenoid and run forward lateral to it.

In the non-siluroid Teleostei the trigemino-facialis chamber is not continuous with the myodome, and it has been separated by a wall of bone into partes ganglionaris and jugularis that correspond, respectively, to the trigemino-facialis recess and the jugular and external carotid canals of the Selachii. The pedicel of the alisphenoid is incomplete, or wholly wanting, but it may be replaced by an anterior prolongation of the ascending process of the para-

sphenoid. In the latter case the nerves, arteries, veins and muscles all have the same relations to this process that they have to the pedicel of the alisphenoid of Amia. The lateral wall of the pars jugularis of the trigemino-facialis chamber is always less extensive than in Amia, and may be wholly wanting.

In Ceratodus there is a trigemino-facialis chamber similar to that in Amia, and there is a bar of cartilage that corresponds to the pedicel of the alisphenoid of that fish.

In the Amphibia there is a trigemino-facialis recess, and the pars ascendens of the quadrate forms the lateral wall of a space that corresponds to the pars jugularis of the chamber of the Teleostei. The ascending process of the palatoquadrate is the homologue of the pedicel of the alisphenoid of fishes.

In the Reptilia there apparently is no trigemino-facialis recess, the lateral wall of the neurocranium being the primitive cranial wall. The pars ascendens of the quadrate forms the lateral wall of a trigemino-facialis chamber. The antipterygoid (columella) is the homologue of the pedicel of the alisphenoid of fishes, and the processus basipterygoideus the homologue of the floor of the orbital opening of the myodome of Amia.

In the Mammalia there is a trigemino-facialis recess formed by the cava epiptericum and supracochleare. The ala temporalis is peculiar to mammals, and is a bar of cartilage formed between the nervi maxillaris and mandibularis trigemini as they issue from the trigemino-facialis recess, the processus alaris corresponding to some part of the side wall of the prespinal portion of the myodome of Amia. The ala temporalis has been prolonged anteriorly so as to enclose a space that lies anterior to the trigemino-facialis recess, and the foras mina for the pituitary vein (sinus cavernous) and the nervi oculomotorius, trochlearis and profundus (first branch of trigeminus) open into this apace and from it into the orbit. The cavum tympanicum is the pars jugularis of the trigemino-facialis chamber, and the processus pterygoideus, the malleus, incus and stapes, and possibly also the annulus tympanicus, are quite certainly portions of the lateral wall of that part of the chamber. A diverticulum of the spiracular canal, or an independent evagination of the pharynx, has expanded into this part of the chamber and so formed the middle ear. The chorda tympani must, then, correspond to that communicating branch from the nervus facialis to the nervus trigeminus that, in fishes, traverses the trigemino-facialis chamber, and hence must be a prespiracular nerve.

The internal carotid artery enters the cranial cavity, in most vertebrates, by passing upward mesial to the related trabecula, or mesial to that posterior prolongation of the trabecula that is formed by the polar cartilage, but in Ameiurus it enters the cranial cavity through the foramen opticum, and hence would seem there to pass lateral and then dorsal to the trabecula. In embryos of the Mammalia ditremata also this artery is said to pass upward lateral to the trabecula, but it is probable that it here simply passes lateral to

the infrapolar process of the polar cartilage, the latter cartilage itself not fusing directly with the parachordal plate, its direct relations to the artery thus being obscured.

[1] Gaupp, E., *Anat. Anz., Jena*, **27**, 1905, (273–310).
[2] Sonies, F., *Petrus Camper*, Deel. 4, Jena, 1907, (395–486), Taf. 7/10.
[3] Noordenbos, W., *Ibid.*, Deel. 3, Jena, 1905, (367–430), Taf. 6/8.

THE EFFECT OF INBREEDING AND CROSSBREEDING UPON DEVELOPMENT[1]

By D. F. Jones

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Communicated by T. B. Osborne, July 12, 1918

The experiments dealing with the effects of inbreeding and crossbreeding in the naturally cross-pollinated corn plant, *Zea mays* L., carried on at the Connecticut Experiment Station have been reported on previously by East[2] and Hayes.[3] A continuation of these experiments shows that there is no appreciable reduction in vigor and productiveness, as indicated by the yield of grain and height of plant, after the eighth generation of self-fertilization as can be seen in table 1. The resulting inbred strains, now in the eleventh

TABLE 1

The Effect of Inbreeding on the Yield and Height of Maize

Year grown	Number of generations selfed	Four inbred strains derived from a variety of Leaming dent corn							
		1-6-1-3-etc.		1-7-1-1-etc.		1-7-1-2-etc.		1-9-1-2-etc.	
		Yield per acre	Height	Yield per acre	Height	Yield per acre	Height	Yield per acre	Height
		bushels	*inches*	*bushels*	*inches*	*bushels*	*inches*	*bushels*	*inches*
1916	0	74.7	117.3	74.7	117.3	74.7	117.3	74.7	117.3
1905	0	88.0		88.0		88.0		88.0	
1906	1	59.1		60.9		60.9		42.3	
1908	2	95.2		(1907) 59.3		(1907) 59.3		51.7	
1909	3	57.9		(1908) 46.0		(1908) 59.7		35.4	
1910	4	80.0		63.2		68.1		47.7	
1911	5	27.7	86.7	25.4	81.1	41.3	90.5	26.0	76.5
1912	6							(1913) 38.9	
1913	7	41.8		39.4				(1914) 45.4	85.0
1914	8	78.8	96.0	47.2	83.5	58.5	88.0	(1915) 21.6	
1915	9	25.5		24.8				(1916) 30.6	78.7
1916	10	32.8	97.7	32.7	84.9	19.2	86.9	(1917) 31.8	82.4
1917	11	46.2	103.7	42.3	78.6	37.6	83.8		

generation of continuous self-fertilization, are remarkably uniform and constant. Very little change in average ear row number or reduction in variability of row number has taken place after the eighth generation in two inbred lines derived originally from the same plant in the second generation of inbreeding as shown in figure 1. These results are in agreement with the theoretical attainment of nearly complete homozygosis automatically in about the eighth generation of self-fertilization. Although the inbred strains are now only about one half as productive as the original variety, the plants, judging from their behavior in the past three years, are capable of being maintained unchanged indefinitely by self-fertilization.

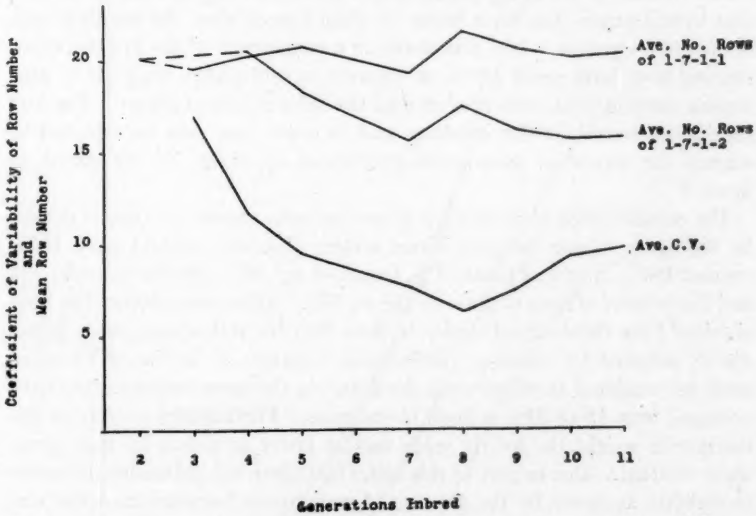

FIG. 1.

In contrast to the uniformity of all the plants within one inbred line is the difference between the several lines. With regard to ear characters two of them have flat cobs and two have round. One has uncolored cobs while the others have colored. They all differ in the shape and size of ears and seeds and in the arrangement of the seeds on the ears. Equally noticeable differences characterize the tassels, stalks and leaves.

One of the most pronounced effects of inbreeding in maize is the appearance of sterility in the form of pollen and ovule abortion. An extreme reduction in the amount of pollen produced is shown frequently in plants long inbred. Not all strains show this, however, as some have well developed anthers and produce abundant pollen. In nearly every case, however, those inbred strains which have the best developed staminate inflorescences have poorly developed pistillate inflorescences and those strains which have the

largest pistillate inflorescences and are most productive of grain produce a very small quantity of pollen. Doubtless many plants are produced which completely lack one or the other or both functions but such types, of course, can not be maintained in self-fertilization. There is, therefore, a decided tendency for inbreeding to change a monoecious plant into a functionally dioecious plant.

All of the inbred strains obtained show an immediate return to the vigorous condition of the non-inbred parents when crossed. The return of vigor is greater in some combinations than in others. In general there seems to be a correlation between the productiveness of the female parent strain and the productiveness of the first generation hybrid. This is in part due to the fact that hybrid plants start from better developed seeds when the female parent is the more vigorous. It is also shown in a comparison of the F_2 generation, starting from large seeds grown on vigorous hybrid plants, with the F_1 generation starting from seeds produced on the reduced inbred plants. The first generation overcomes this handicap and in every case may be expected to surpass the second or subsequent generations as shown by the curves in figure 2.

The manifestation of heterosis is greater in some characters than in others. In the many crosses between inbred strains observed yield of grain is increased 180%, height of plant 27%, length of ear 29%, number of nodes 6% and the number of rows of grain on the ear 5%. Abundant evidence has been obtained from these inbred strains to show that the endosperm also is immediately affected by crossing. Differences in weight of reciprocally crossed seeds as compared to selfed seeds developed in the same inflorescences have averaged from 15 to 20% in favor of the cross. Furthermore in spite of this increase in weight the hybrid seeds mature faster as shown by their lower water content. Due in part to this latter fact there is a noticeable difference in viability as shown by the per cent of germination between the selfed and crossed seeds produced by the same plants. The crossed seedlings also appear from one to two days earlier than the selfed seedlings.

In view of the notable advantages to be gained from cross-fertilization it was thought that when mixtures of a plant's own pollen with that of a distinct sort were applied there might be a selective fertilization favoring the foreign pollen. By taking advantage of xenia it was possible to obtain and to distinguish selfed and reciprocally crossed seeds from plants of two different inbred strains. Since the same mixture of pollen was applied to plants of both strains, the number of seeds produced by one kind of pollen should be in the same ratio to the number of seeds produced by the other kind of pollen, on both types of plants to which the mixture was applied, irrespective of the amounts or viability of the two kinds of pollen used. Any deviation from a perfect proportion in the form of an excess of crossed seeds or an excess of selfed seeds would indicate selective fertilization in one or the other

direction. A large amount of data has been obtained in this way which shows that there is no inequality in fertilizing ability favoring foreign pollen. In fact the data show a selection in the other direction large enough to have

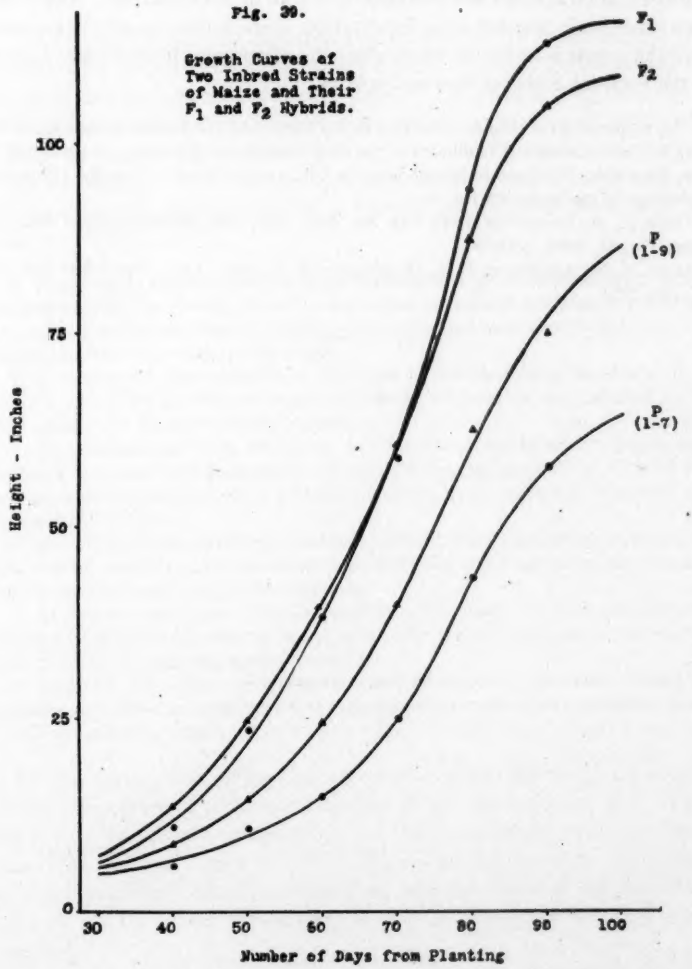

FIG. 2.

significance when compared to the probably error. Whether this is really the case or whether there has been a constant error in classifying the seeds will have to await the growing of the plants from these seeds in order to deter-

mine the accuracy of the classification. In the meantime it hardly seems possible that the error could be so great as to hide an actual selective fertilization in favor of cross-pollination, since the inbred strains are so uniform in color of endosperm and the crossed seeds usually so distinct that the error of classification is small and presumably not all in one direction. And if there is no selection in favor of cross-fertilization, there is then no effect of crossing until the zygote is formed however great the advantages immediately accruing to the resulting embryos and endosperms.

[1] An extract from a treatise submitted to the faculty of the Bussey Institution of Harvard University in partial fulfillment of the requirements for the degree of Doctor of Science, December, 1917, and to be published in full as a contribution from the Connecticut Agricultural Experiment Station.

[2] East, E. M., *Connecticut Agric. Exp. Sta. Rep.*, 1907, 1908, (419–428); *Amer. Nat., Lancaster, Pa.*, **43**, 1909, (173–181).

[3] East, E. M., and Hayes, H. K., *Washington, U. S. Dept. Agric., Bur. Plant Ind. Bull.* No. 243, 1912.

NATIONAL RESEARCH COUNCIL

EXECUTIVE ORDER ISSUED BY THE PRESIDENT OF THE UNITED STATES MAY 11, 1918

The National Research Council was organized in 1916 at the request of the President by the National Academy of Sciences, under its Congressional charter, as a measure of national preparedness. The work accomplished by the Council in organizing research and in securing co-operation of military and civilian agencies in the solution of military problems demonstrates its capacity for larger service. The National Academy of Sciences is therefore requested to perpetuate the National Research Council, the duties of which shall be as follows:

1. In general, to stimulate research in the mathematical, physical and biological sciences, and in the application of these sciences to engineering, agriculture, medicine and other useful arts, with the object of increasing knowledge, of strengthening the national defense, and of contributing in other ways to the public welfare.
2. To survey the larger possibilities of science, to formulate comprehensive projects of research, and to develop effective means of utilizing the scientific and technical resources of the country for dealing with these projects.
3. To promote co-operation in research, at home and abroad, in order to secure concentration of effort, minimize duplication, and stimulate progress; but in all co-operative undertakings to give encouragement to individual initiative, as fundamentally important to the advancement of science.
4. To serve as a means of bringing American and foreign investigators into active co-operation with the scientific and technical services of the War and Navy Departments and with those of the civil branches of the Government.
5. To direct the attention of scientific and technical investigators to the present importance of military and industrial problems in connection with the war, and to aid in the solution of these problems by organizing specific researches.
6. To gather and collate scientific and technical information at home and abroad, in co-operation with Governmental and other agencies and to render such information available to duly accredited persons.

Effective prosecution of the Council's work requires the cordial collaboration of the scientific and technical branches of the Government, both military and civil. To this end representatives of the Government, upon the nomination of the National Academy of Sciences, will be designated by the President as members of the Council, as heretofore, and the heads of the departments immediately concerned will continue to co-operate in every way that may be required.

(Signed) WOODROW WILSON.

THE WHITE HOUSE
May 11, 1918.

NATIONAL RESEARCH COUNCIL

MINUTES OF THE SECOND MEETING OF THE EXECUTIVE BOARD OF THE WAR ORGANIZATION IN JOINT SESSION WITH THE COUNCIL OF THE NATIONAL ACADEMY OF SCIENCES

TUESDAY, MARCH 26, 1918

The meeting convened at 9.30 a.m. in the offices of the National Research Council, 1023 Sixteenth Street, Washington, D. C., with President Walcott of the National Academy of Sciences, in the chair.

Present: Members of Council of National Academy of Sciences: Whitman Cross, George E. Hale, Arthur A. Noyes, Charles D. Walcott; members of Executive Board of National Research Council: Whitman Cross, Gano Dunn, George E. Hale, John Johnston, Vernon L. Kellogg, Charles E. Mendenhall, Robert A. Millikan, Arthur A. Noyes, Richard M. Pearce, S. W. Stratton, Charles D. Walcott, and Robert S. Woodward, and by invitation: Henry M. Howe and S. L. G. Knox.

The minutes of the first meeting of the Executive Board of the War Organization of the Research Council, of February 26, 1918, were presented and approved.

The Chairman of the Research Council reported:

1. That the Rockefeller Foundation has made an appropriation of $50,000 to provide for the expenses of the Division of Medicine and Related Sciences for the period from March 1 to December 31, 1918, and that sums, as needed, from this appropriation, will be deposited with the National Academy of Sciences for disbursement upon approval of the Chairman of this Division.

2. That Dr. W. W. Keen has donated the sum of $382.22 for the work of the Council, and that this amount, representing proceeds from sales of a book entitled *The Treatment of War Wounds*, which was prepared by him in connection with his activities as a member of the Council, has been deposited to the credit of the Council with the National Academy of Sciences.

3. That Graham Edgar has assumed his duties in Washington as Technical Assistant of the Research Information Committee, and that W. M. Gilbert will act as Secretary of the Washington office of this Committee.

4. That the Engineering Foundation has approved the designation of the Secretary of the Foundation as Assistant Secretary of the National Research Council, as authorized by the Executive Board of the Council at its meeting of February 26, 1918; and that the Engineering Foundation has reciprocally appointed the Secretary of the National Research Council as an Assistant Secretary of the Engineering Foundation.

The Chairman of the Council submitted the following report of action taken by the Interim Committee of the Executive Board of the Council at a meeting held on Tuesday, March 19:

1. That by reason of his appointment as Chief of the Chemical Service Section of the National Army, Mr. Bogert has resigned as Chairman of the Division of Chemistry and Chemical Technology of the Council, and that upon nomination of the Executive Committee of the Division, Mr. John Johnston has been elected Chairman.

2. That the resignations of Mr. E. G. Conklin as Chairman of the Zoölogy Committee and of Mr. W. H. Holmes as Chairman of the Anthropology Committee of the Council, have been accepted.

3. That an Executive Committee of the Division of Agriculture, Botany, Forestry, Fisheries and Zoölogy, has been appointed as follows: Vernon L. Kellogg, Chairman, Irving W. Bailey, Karl F. Kellerman, Burton E. Livingston, H. F. Moore, Raphael Zon.

4. That a Committee on Medical Zoölogy of the Division of Medicine and Related Sciences has been appointed as follows:

Representatives of Entomology:

Leland O. Howard, U. S. Department of Agriculture, Washington, D. C. (Chairman of Group).

Charles T. Brues, Bussey Institute, Forest Hills, Massachusetts.

W. A. Riley, Cornell University, Ithaca, New York.

Representatives of Protozoölogy:

C. A. Kofoid, University of California, Berkeley, California (Chairman of Group), (Major S. C. N. A., Fort Sam Houston, Texas).

Theobald Smith, Rockefeller Institute, Princeton, New Jersey.

Frederick G. Novy, University of Michigan, Ann Arbor, Michigan.

Representatives of Helminthology:

Henry B. Ward, University of Illinois, Urbana, Illinois (Chairman of Group).

Charles W. Stiles, U. S. Public Health Service, Washington, D. C.

Allen J. Smith, University of Pennsylvania, Philadelphia, Pennsylvania.

5. That a Sub-Committee of the Committee on Psychology, to deal with pedagogical and psychological problems of Military Training and Discipline, has been appointed as follows, upon recommendation of the Chairman of the Division of Medicine and Related Sciences:

William C. Bagley, Carnegie Foundation for the Advancement of Teaching, Chairman.

Charles H. Judd, University of Chicago.

A. Caswell Ellis, University of Texas.

6. That upon recommendation of the Vice-Chairman of the Division of Geology and Geography, and in accordance with action of the Executive Board at its meeting of February 26, an allotment of $1,000 or so much thereof as may be necessary, has been authorized from funds available to the National Research Council, in case such sum cannot be obtained from the U. S. Government, to provide for the expenses of an assistant to Major D. W. Johnson in Europe, when engaged in work for the Division of Geology and Geography, the disbursement of this allotment to be made through the Research Information Committee in Paris. Major Johnson, while assigned primarily to other duty in Europe, has obtained permission and has been formally authorized to act as the representative of the Division of Geology and Geography.

The Chairman of the Council furthermore reported the following recommendations:

1. From the Executive Committee of the Division of Chemistry and Chemical Technology:

(a) That the following be added to membership in the Chemistry Committee:

William J. Comstock, formerly of Chemistry Department, Yale University.

Samuel Avery, Chancellor, University of Nebraska.

(b) That the special Committee on Platinum and Related Metals of the Chemistry Committee, be changed to a Sub-Committee, and that a Sub-Committee on Primers of the Chemistry Committee be appointed as follows:

Richard C. Tolman, Chairman, C. McPhail Smith, H. E. Eastlack.

(c) That nominations submitted by the Institute of Chemical Engineers for membership in the Sub-Committee on Chemical Engineering of the Chemistry Committee, be accepted as follows:

Charles F. McKenna, New York.
G. W. Thompson, Chief Chemist, National Lead Company.
Richard K. Meade, Consulting Chemical Engineer, Brooklyn.
Hugh K. Moore, Chief Chemist and Chemical Engineer, Berlin Mills Company.
William C. Carnell, care of Chas. Lennig & Co., Philadelphia.

2. From the Division of Physics, Mathematics, Astronomy and Geophysics:

That the following be added to membership in the Sub-Committee on Location of Invisible Aircraft of the Physics Committee:

Henry N. Russell, E. O. Dietrick, O. Stuhlman.

Upon motion, the acts of the Interim Committee of the Council as reported above were ratified and confirmed, and the recommendations submitted from the Division of Chemistry and Chemical Technology and from the Division of Phycics, Mathematics, Astronomy and Geophysics, were approved and the appointments made.

A vote of thanks to Mr. Bogert was offered and adopted, in appreciation of his successful labors and effective coöperation as Chairman of the Division of Chemistry and Chemical Technology. The resignations of Mr. Conklin and of Mr. Holmes were also accepted with expression of appreciation of the valuable work they accomplished.

Votes of thanks and appreciation were adopted relative to the donations for the work of the Council, received from the Rockefeller Foundation and from Dr. W. W. Keen.

Upon nomination of the Chairman, Mr. Noyes was elected Chairman of the Administrative Division of the Council.

Upon nomination of the Chairman, the President of the National Academy of Sciences was requested to appoint the following additional member of the Council:

Walter S. Gifford, Director, Council of National Defense.

Upon motion Mr. Gifford was also appointed a member at large of the Executive Board of the Council, and a member of the Military Division.

Mr. French, editor of the *Journal of the American Society of Mechanical Engineers*, appeared before the Board, upon the suggestion of Mr. Dunn, and explained a proposal previously submitted by this Society to supply titles and abstracts of published papers relating to research in engineering and allied subjects, offering to place the facilities of their organization at the disposal of the Council and its Research Information Committee. With a cordial vote of thanks to the American Society of Mechanical Engineers for this evidence of continued assistance to and coöperation with the Research Council, the Executive Board accepted the offer submitted by Mr. French, and accordingly the Research Information Committee was authorized to formulate definite methods for effective coöperation.

Mr. Walcott called attention to the fact that by action of the Executive Committee of the Research Council, in January, 1917, all government appointees of the Council residing in Washington became thereupon members of the Military Committee. Discussion revealed the desirability of limiting

the membership of this Committee and of the newly organized Military Division of the Council, and accordingly it was

RESOLVED: That the Military Division of the Council consist of the heads or acting heads of government bureaus in Washington, who have been appointed members of the National Research Council.

Membership of the Division at present consists of:

Charles D. Walcott, Chairman
S. W. Stratton, Vice-Chairman
Carl L. Alsberg
Admiral William S. Benson
Maj.-General William M. Black
Howard E. Coffin
Maj.-General William Crozier
Rear-Admiral Ralph Earle
Walter S. Gifford
Major-General Willliam C. Gorgas
Rear Admiral Robert S. Griffin
Brigadier-General P. D. Lockridge
Van H. Manning
Charles F. Marvin
George O. Smith
Major-General George O. Squier
Rear-Admiral David W. Taylor
Colonel Ralph H. Van Deman
Captain Roger Welles

Mr. Cross reported that the proposed allotment of a sum not to exceed $5,000 as discussed at the meeting of the Executive Board of February 26 and referred to the Interim Committee with authority to act, has become unnecessary in view of a change of plan relative to the special monograph work concerned. On the other hand, he submitted a request from the Military Intelligence Section of the Army for advice and assistance in connection with other monograph work.

After discussion it was voted that the National Research Council accept the invitation of the Chief of the Military Intelligence Section, Executive Division of the General Staff, U. S. A., to furnish a list of the names of persons who can supply information desired for proposed special monographs and that a committee of three be appointed by the Chairman of the Council to take charge of this work. Thereupon, Mr. Hale appointed this committee as follows:

Whitman Cross, Chairman, Henry M. Howe, Alfred D. Flinn.

Upon motion, a special committee of three members of the National Research Council, consisting of Messrs. Dunn, Millikan and Noyes, was appointed to serve in joint session with the special committee of the National Academy of Sciences, referred to above, for the consideration and formulation of proposals relative to the future extension of the work of the Academy and Council, including the accumulation of endowment funds and the construction of suitable buildings.

Mr. Hale reported that Dr. Arthur Schuster, Secretary of the Royal Society, had suggested the desirability of organizing an international conference of scientific academies during the coming summer. Upon motion, the Chairman of the meeting was requested to appoint a committee of three members of the National Academy of Sciences to consider this question. Mr. Hale, Mr. Noyes and Mr. Howe were appointed members of such a Committee, the President of the National Academy of Sciences to act also as an ex officio member.

The meeting adjourned at 12.10 p.m.

MINUTES OF THIRD MEETING OF EXECUTIVE BOARD OF WAR ORGANIZATION

TUESDAY, APRIL 30, 1918

The meeting convened at 9.30 a.m. in the offices of the Council at 1023 Sixteenth Street, with Mr. Hale, Chairman of the Council, in the chair.

Present: Whitman Cross, George E. Hale, Henry M. Howe, John Johnston, Vernon Kellogg, Van H. Manning, John C. Merriam, Robert A. Millikan, Richard M. Pearce, S. W. Stratton, Charles D. Walcott, William H. Welch, Robert S. Woodward, and Robert M. Yerkes, and by invitation, Graham Edgar.

The minutes of the Second Meeting of the Executive Board of the War Organization, of March 26, 1918, were presented and approved.

The Chairman of the Council reported:

1. That a suggestion for the International Organization of Science and Research has been submitted to and approved by the Council of the National Academy of Sciences and has been forwarded to the President of the United States and to the Secretary of State for ratification, and to representatives of the Academy abroad, for presentation, if ratified, at a preliminary international conference of scientific academies to be held in London on May 8, 1918.

The Chairman of the Council presented the following report of action taken by the Interim Committee of the Executive Board of the Council at meetings held on Thursday, April 18, and Monday, April 29.

1. That the following appointments have been made:

Arthur A. Noyes, Chairman of Interim Committee.

J. C. Merriam, Chairman of Section on Relations with Educational Institutions and State Research Councils.

Henry M. Howe, Chairman of Engineering Division.

L. H. Baekeland, Acting Chairman of the Patent Office Committee.

C. E. McClung, member and acting Chairman of Zoölogy Committee.

Oakes Ames and C. E. McClung, members of Executive Committee of Division of Agriculture, Botany and Zoölogy.

John W. Baird, Professor of Psychology, Clark University, Vice-Chairman of Psychology Committee.

Rufus I. Cole, Director of Rockefeller Hospital, member of Executive Committee of Division of Medicine and Related Sciences.

Reid Hunt, Professor of Pharmacology, Harvard Medical School, Representative of medical profession as member of Patent Office Committee.

E. G. Martin, Professor of Physiology, Leland Stanford University, member of Sub-Committee on Muscular Work and Fatigue of Physiology Committee.

Dwight W. Fisher, Chief Clerk of the Council.

2. That the resignation of Colonel William H. Walker as Vice-Chairman of the Division of Chemistry and Chemical Technology has been accepted.

3. That the following have hitherto accepted appointment as members of the Advisory Committee of the Section on Industrial Research: Elihu Root, Theodore N. Vail, Henry S.

Pritchett, Edwin Wilbur Rice, Jr., George Eastman, A. W. Mellon, Pierre S. duPont, and Elbert H. Gary.

4. That the following special Committee on Fertilizers has been appointed, to be composed of two representatives each from the Division of Chemistry and Chemical Technology and the Division of Agriculture, Botany and Zoölogy, said Committee to report to the Chairman of each of these Divisions:

Samuel Avery, Chairman, Chancellor, University of Nebraska.

Homer J. Wheeler, American Agricultural Chemical Company.

Karl F. Kellerman, U. S. Dept. of Agriculture.

Albert F. Woods, President, Maryland State College.

5. That it is inadvisable at present to organize a special section on Governmental Relations of the Administrative Division.

6. That the Research Information Committee shall be considered as the Information Section of the Administrative Division.

7. That the National Advisory Committee for Aeronautics has been invited to act as the Section on Aeronautics of the Engineering Division and that Dr. Charles D. Walcott has been asked to serve as Chairman of this Section.

8. That the title of the Sub-Committee on Fatigue and Industrial Pursuits of the Physiology Committee has been changed to the Sub-Committee on Muscular Work and Fatigue.

9. That the name of the Section on Design of the Engineering Division has been changed to the Section on Mechanical Engineering.

10. That the personnel and work of the Sub-Committee on Biochemistry of the Division of Chemistry and Chemical Technology has been transferred to the jurisdiction of the Division of Medicine and Related Sciences.

11. That in view of existing requirements for war purposes and of the impossibility at present of carrying out plans as originally outlined by the Anthropology Committee, it was voted to substitute for this Committee a number of special committees to cover the particular needs within this field as they arise. The following special committees have been appointed:

Anthropometry in the Army:

C. B. Davenport, Chairman, Ales Hrdlicka, Secretary, E. A. Hooton.

Race in Relation to Disease:

Military Section: Col. A. G. Love, Chairman, Major F. H. Garrison, W. F. Willcox.

Civilian Section: F. S. Hoffman, Chairman.

12. That the use of franking privileges by committees or subcommittees of the Council will be permitted only upon authorization by the Interim Committee.

13. That it has been decided to issue a pamphlet concerning the War Organization of the Council, to include the names of the General Officers and Executive Board, and the names and Chairmen of the various Divisions and of their Sections and Committees.

14. That a section on electrical engineering of the Engineering Division has been established, and that Comfort A. Adams has been appointed chairman of this section, provided it will be possible for him to take active charge of the work.

15. That upon nomination of the Chairman of the Council, the President of the National Academy of Sciences has been requested to appoint the following additional member of the Council:

Henry S. Graves, Forester and Chief of the Forest Service.

Mr. Graves was also named as member of the Military Division.

16. That the following allotments have been authorized upon recommendation of the Division of Medicine and Related Sciences to be paid from the appropriation made by the Rockefeller Foundation for the expenses of this Division.

(a) A sum of $500.00 or as much thereof as may be necessary to meet the traveling expenses of the members of the Sub-Committee on Shock of the Physiology Committee in connection with a conference of this Sub-Committee to be held in Baltimore on April 19 and 20.

(b) A sum of $1,000.00 to Dr. D. R. Hooker, Johns Hopkins Medical School, for experimental investigations to be carried on at the Sandy Hook Proving Station on the influences of high explosives in producing conditions of shock.

(c) A sum of $100.00 to Dr. William Moore to cover expenses of collecting, breeding and storing lice in connection with his investigations of the louse problem in relation to trench fever.

17. That the following allotments have been authorized for investigations under the auspices of the Division of Agriculture, Botany and Zoölogy to be paid from the appropriation made available by the Carnegie Corporation of New York for the general expenses of the Council:

(a) A sum of $1,000.00 for an investigation of the relation of rodent pests to their environment, especially with relation to forage and grain crops, the work to be carried on in cooperation with the U. S. Biological Survey.

(b) A sum of $600.00 for an investigation of lac and lac insects in the South-West including provision for traveling expenses and maintenance of a field assistant in carrying on a survey of the abundance of this material and of the possibility of its exploitation, and in undertaking at the same time a study of the growth and of the commercial possibilities of mesquite gums.

(c) A sum of $2,000.00 for active coöperation with the War Emergency Board of the American Association of Plant Pathologists for the purpose of aiding the work of this Board.

18. That the following allotment has been authorized for expenditure under the auspices of the Engineering Division, to be charged against the appropriation made available by the Carnegie Corporation of New York for the general expenses of the Council:

(a) A sum of $4,000.00 for traveling and incidental expenses of members of the Division.

After discussion of special recommendations submitted by the Interim Committee, the following resolutions were adopted by the Executive Board:

RESOLVED, That in view of the demands of the war situation, the general policy of the National Research Council shall be to replace the general committees previously established by special committees for specific needs unless it is possible for such existing committees to serve effectively for war purposes.

RESOLVED, That in view of the importance, particularly under war conditions, of securing regular attendance at meetings of the Executive Committees of the Divisions of the Council each Division be and hereby is authorized and requested to formulate regulations with regard to such attendance, due consideration being given to the needs and work of the Division in question.

RESOLVED, That the Divisions of the Council be and hereby are requested if practicable to arrange for regular and stated meetings of the Executive Committees of the Divisions during the first week of each month, and that regular meetings of the Executive Board shall be held on the second Tuesday of each month.

RESOLVED, That the Treasurer be and hereby is authorized to sign checks drawn on available funds of the National Research Council to cover traveling expenses of members of the Executive Board of the Council, and traveling and incidental expenses in connection with the prosecution of work of the Divisions of the Council; vouchers for such expenditures to be submitted to the Treasurer with the approval of the Chairman of the Division concerned or of the Chairman of the Council, as circumstances require.

The Chairman of the Council also reported that the Italian Ambassador in Washington has received a request from the Italian Minister of Munitions for the establishment of an office of the Committee in Rome to undertake work similar to that performed by the offices in London and Paris. After discussion, the Chairman of the Council was authorized to appoint a representative of the Research Information Committee for the proposed office

in Rome, in case the Council of National Defense provides for the establishment of this office.

Mr. Howe, Chairman of the Engineering Division, outlined plans for active coöperation with the national engineering societies primarily with reference to war needs, but also as a preparation for future work. Upon motion, the Executive Board approved his program and authorized him to proceed with its development and application.

Mr. Johnston, Chairman of the Division of Chemistry and Chemical Technology, after outlining briefly the activities of his Division, which include frequent conferences and the organization of small groups of active workers to deal with special problems, was authorized, upon motion, to proceed with his program and complete the plan of organization of the Division.

Mr. Merriam, Chairman of the Division of Geology and Geography, reported that, after due consideration, it has been decided to continue the Committees previously established by the Council in these fields as active sub-committees of the divisional organization, and that additional special committees will be appointed with the understanding that all such units of organization will report to the Chairman of the Division. Colonel Welch enquired whether the Division of Geology and Geography is in a position to furnish recommendations, after investigation, of desirable sites for training camps in the United States. The Chairman of the Division was requested to confer with Colonel Welch on this subject.

Colonel Millikan outlined briefly his proposal for weekly conferences of members of the Physics and Engineering Divisions of the Council, and was authorized, upon motion, to proceed with the organization of such conferences.

Upon nomination by Colonel Millikan, the following Executive Committee of the Division of Physics, Mathematics, Astronomy, and Geophysics, was appointed: Joseph S. Ames, Louis A. Bauer, Arthur L. Day, Charles F. Marvin, Major Charles E. Mendenhall, Lieut. Col. R. A. Millikan, F. R. Moulton, Ernest F. Nichols, H. N. Russell, W. C. Sabine, Frank Schlesinger, General George O. Squier, Samuel W. Stratton, Robert S. Woodward.

Mr. Pearce, Chairman of the Division of Medicine and Related Sciences, reported upon the progress of the work of his Division, specially with regard to satisfactory coöperation which is being maintained with the Surgeon General's Office of the Army.

Mr. Kellogg, Chairman of the Division of Agriculture, Botany and Zoölogy, outlined briefly the nature of problems which are under consideration by his Division in relation to food production and conservation, and reported especially upon work of coördination with the United States Department of Agriculture.

Discussion took place relative to the appointment as members of the National Research Council, of all members of the Executive Committees of the Divisions of the Council, and after due consideration it was

RESOLVED, That future appointments to membership in the National Research Council shall be limited to the period of the war, and that the terms of office of all members of the Council, as such, shall expire at the end of the war, pending the establishment of a permanent organization for the Council.

Upon motion, the President of the National Academy of Sciences was requested to appoint the following additional members of the Council, who, at present, are members of Executive Committees of Divisions:

Oakes Ames, Assistant Professor of Botany, Harvard University.

Irving W. Bailey, Assistant Professor of Forestry, Harvard University.

Louis A. Bauer, Director, Dept. of Terrestrial Magnetism, Carnegie Institution of Washington.

Karl F. Kellerman, Associate Chief, Bureau of Plant Industry, U. S. Dept. of Agriculture.

Burton E. Livingston, Professor of Plant Physiology, Johns Hopkins University.

Clarence E. McClung, Director of Zoölogical Laboratory, University of Pennsylvania.

Henry F. Moore, Deputy Commissioner, U. S. Bureau of Fisheries.

Ernest F. Nichols, professor of Physics, Yale University.

F. R. Moulton, Professor of Astronomy, University of Chicago.

Henry N. Russell, Professor of Astronomy, Princeton University.

Wallace C. Sabine, Hollis Professor of Mathematics and Natural Philosophy, Harvard University.

Frank Schlesinger, Director, Allegheny Observatory.

Raphael Zon, Chief, Office of Forest Investigation, U. S. Forest Service.

Rufus Cole, Director, Hospital of Rockefeller Institute.

The Chairman of the Council outlined the financial needs of the various Divisions of the Council, referring particularly to proposed activities of the Division of Engineering and of the Division of Agriculture, Botany, and Zoölogy and emphasized the necessity for the preparation of a budget for the Council. Upon motion, the Chairman was requested to appoint a special committee to construct such a budget, with instructions to confer with the Chairman of Divisions relative to respective needs, and to report at the next meeting of the Interim Committee, the Chairman of the Council to be an ex officio member. The other members of the Committee were appointed by the Chairman as follows: Arthur A. Noyes, Chairman, Whitman Cross, John C. Merriam.

The meeting adjourned at 11.50 a.m. with the understanding that the next meeting of the Executive Board will be held as authorized on Tuesday, June 11, 1918, at 9.30 a.m.

JOHN JOHNSTON, *Secretary.*

REPORT OF THE ANNUAL MEETING

PREPARED BY THE HOME SECRETARY

The Annual Meeting of the Academy was held in the Smithsonian Institution in Washington, April 22, 23, and 24, 1918.

Fifty-eight members were present as follows: C. G. Abbot, Ames, Bailey, Becker, Benedict, W. W. Campbell, Carty, F. W. Clarke, J. M. Clarke, Conklin, Crew, Cross, Dall, Davenport, Davis, Donaldson, Fewkes, Flexner, Hale, Halsted, Hillebrand, Howard, Howell, Iddings, Kasner, Lillie, Meltzer, Mendel, T. C. Mendenhall, Merriam, Michelson, Millikan, E. S. Morse, Moulton, E. L. Nichols, E. F. Nichols, A. A. Noyes, W. A. Noyes, H. F. Osborn, Pearl, Pupin, Ransome, Reid, Rosa, Schlesinger, Erwin F. Smith, Stratton, Thomson, Ulrich, Van Hise, Van Vleck, Walcott, Webster, Welch, Wheeler, D. White, Wilson, Woodward.

BUSINESS SESSIONS

The President announced that the Home Secretary, Mr. Arthur L. Day would not be present, owing to absence from the city on matters relating to war.

REPORTS FROM OFFICERS OF THE ACADEMY

The annual report of the President to Congress for 1916 was presented and distributed.

The President presented the following communication from Mr. R. S. Woodward, resigning the chairmanship of the Committee on the Barnard Medal:

April 9, 1918.

The Home Secretary,

DEAR SIR:

Permit me to tender through your office to the Council of the National Academy of Sciences my resignation as Chairman of the Committee on the Barnard Medal. Like our late colleague, Profesor William James, I find that with advancing years it is desirable to relieve oneself of what he fittingly called "life's baggage." Having assisted at the birth of many of our American Societies and served them in one way or another for many years, and having acted as the Chairman of the Committee on the Barnard Medal for a decade, I am disposed to think it will be advantageous for me, for the Academy, and for contemporary society to transfer the duties of the Chairmanship of the Committee in question to a younger man.

Faithfully yours,

ROBERT S. WOODWARD.

MOVED: That the resignation of Mr. Robert S. Woodward as Chairman of the Committee on the Barnard Medal be accepted with regret, that Mr. T. H. Morgan be elected a member of the Committee, and that Mr. A. A. Noyes be elected Chairman. (Adopted.)

The President announced the following changes in the personnel of the Sections and Committees:

Section of Geology and Paleontology: J. M. CLARKE, Chairman.

Section of Botany: ERWIN F. SMITH, Chairman.

Section of Anthropology and Psychology: J. WALTER FEWKES, Acting Chairman.

Local Committee: WHITMAN CROSS, Chairman, DAVID WHITE, FREDERICK L. RANSOME, RAYMOND PEARL, EDWARD O. ULRICH.

Other committee appointments with dates of expiration, were as follows:

Program: E. L. THORNDIKE to serve unexpired term of J. MCKEEN CATTELL 1920.

Henry Draper Fund: GEORGE E. HALE, to succeed himself, 1923.

J. Lawrence Smith Fund: E. S. DANA to succeed himself, 1923.

Comstock Fund: E. L. NICHOLS to succeed himself as member and Chairman ,1923.

Marsh Fund: CHARLES SCHUCHERT to succeed himself, 1921.

Murray Fund: WILLIAM H. DALL to succeed himself as member and Chairman, 1921.

Marcellus Hartley Fund: HENRY F. OSBORN and MICHAEL I. PUPIN to succeed themselves, 1921.

Barnard Medal: A. A. NOYES, Chairman; T. H. MORGAN to succeed R. S. WOODWARD.

The report of the Treasurer was presented in printed form and approved.

The report of the Home Secretary was presented as follows:

April 22, 1918.

The President of the National Academy of Sciences.

SIR: I have the honor to present the following report on the publications and membership of the National Academy of Sciences for the year ending April 24, 1918.

No Scientific Memoirs have been published during the year, but "The Complete Classification of the Triad Systems in Fifteen Elements," by H. S. White, F. N. Cole and Miss L. D. Cummins, recommended to be published as one of the Memoirs of the National Academy of Sciences, was approved by the Committee on Publication and is now in the hands of the Public Printer. The actual publication may be delayed, owing to war conditions.

Of the Biographical Memoirs, that of John Shaw Billings, by S. Wier Mitchell, with the Scientific Work of John Shaw Billings, by Fielding H. Garrison; and William Stimpson, by Alfred G. Mayer, have been published. The former has been distributed, while that of Stimpson has just come from the printer. The manuscript of the Biographical Memoir of James Wright Dana, by L. V. Pirsson, Cleveland Abbe, by W. J. Humphreys, and William Bullock Clark, by John M. Clarke, are in the hands of the Committee on Printing; that of Benjamin O. Peirce, by Edwin H. Hall, is now in galley proof.

The Annual Report for 1917 has been published and is ready for distribution. The Proceedings of the Academy have been published regularly and have reached the third number of the fourth volume.

Four members have died since the last meeting. William Bullock Clark, elected in 1908, died July 27, 1917; James M. Crafts, elected in 1872, died June 21, 1917; Arnold Hague, elected in 1885, died May 15, 1917; Franklin Paine Mall, elected in 1907, died November 17, 1917, and one foreign associate, Adolf von Baeyer, died in August, 1917.

Fifteen new members were elected in April, 1917, making 157 active members on the present membership list; one honorary member and 36 foreign associates.

ARTHUR L. DAY, *Home Secretary.*

REPORTS FROM COMMITTEES ON TRUST FUNDS

A report was received from the Directors of the Bache Fund, signed by Edwin B. Frost (Chairman), stating that since the annual meeting of the Academy in April, 1917, grants Nos. 205–209 (as announced in the PROCEEDINGS, p. 273, below) had been made; and that reports on these and previous grants had been received as follows:

No. 193, C. A. KOFOID, University of California, for assistance in securing animals in the Indian jungle and in their preparation for study in research on the intestinal protozoa. Mr. Kofoid is serving as Major in the Sanitary Corps and the work is being continued by research assistants on the material collected during Mr. Kofoid's travels.

No. 202, W. C. ALLEE, Lake Forest College, Illinois. Research concluded on 'The salt content of natural waters in relation to rhectaxis in Asellus," *Biol. Bull., Woods Hole*, **32**, 93–971. Preliminary results on first phases of investigation concerning a possible correlation between CO_2 production and phototaxis are completed and are in the hands of the editors of *J. Exp. Zool., Philadelphia*. Research is in progress concerning the cause of formation of aggregations of may-fly nymphs and other reactions, and to CO_2 production. Also effect of molting on both above factors; also as to effect of the cyanides on respiration and reactions to various stimuli.

No. 203, J. P. IDDINGS, Brinklow, Maryland. The chemical analysis of igneous rocks collected in Asia and Australasia is completed and the results published in the PROCEEDINGS of this Academy. The work with the microscope and thin sections will continue for some years to come.

No. 204, IRVING W. BAILEY, Bussey Institution, Harvard University, for field data for a study of environment upon the anatomical structure of angiosperms. Cancelled and the money returned to the Treasurer because it was found impracticable for Professor Bailey to go to Guatemala under present war conditions.

No. 205, T. H. GOODSPEED, University of California. Between 20,000 and 25,000 measurements in the flower-size investigations on Nicotiana were made duringt he summer and fall of 1917. These experiments are to be concluded during the summer and results published thereafter.

No. 206, REGINALD A. DALY, Harvard University. The deep sea thermograph has been completed and a description has been published by its designer, Mr. Harry A. Clark, in *Bull. Mus. Comp. Zool., Harvard College*, **61**, No. 15.

No. 209, CECIL K. DRINKER, Harvard Medical School. Research still in progress. A paper, entitled "The factors concerned in the appearance of nucleated red blood corpuscles in the peripheral blood. II. Influence of procedures designed to increase the rate of blood flow through the blood-forming organs—hemorrhage and infusion," by Cecil K. Drinker Katharine R. Drinker and Henry A. Kreutzmann, was published in *J. Exp. Med.*, **27**, 383–397, 1918.

The Directors have voted to transfer to capital account the sum of $2,575, which has been carried for a number of years as 'invested income,' together with $425 of current income, so that the principal of the fund now stands at $59,000.

An effort is being made to pay the American collaborators of the 'Nomenclator Animalium Generum et Subgenerum' the amounts due them for their work. A grant of $1,000 was made in 1913 to Professor F. E. Schulze, of Berlin, specifically for assistance by American men of science in this undertaking It now seems probable that these men can soon receive their compensation. After providing for this liability of $1,000, the cash on hand available for grants. on April 15, 1918, is $10.81.

A report was received from the Trustees of the Watson Fund, signed by A. O. Leuschner (Chairman), W. L. Elkins, and G. C. Comstock, stating that grants Nos. 16–17 (as announced below, p. 273) were recommended. Reports on previous grants were as follows:

No. 14, JOHN A. MILLER, Sproul Observatory, Swarthmore College, is expending his appropriation for the services of an assistant in parallax determinations. A list of 50 parallaxes, together with a list of observations and reductions, has been published. A second list of 50 should be ready before the beginning of January, 1919.

No. 15, HERBERT C. WILSON, Goodsell Observatory, Northfield, Minn., is expending the appropriation for the services of an assistant in measuring and reducing photographic plates of asteroids for position and magnitude. The measurement and reduction of 97 plates has been completed. For 71, the results are published in *Pub. Goodsell Obs., Northfield, Minn.*, No. 5. Of the 26 unpublished measures, 15 are of plates of seven Watson Asteroids. A highly satisfactory color screen suitable for the 16-inch telescope has been made by R. J. Wallace, Research Laboratories of the Cramer Dry Plate Company.

A report was received from the Committee on the Henry Draper Fund, signed by W. W. Campbell (Chairman), as follows:

No awards have been made in the past year: the reduced size of many observatory and laboratory staffs, because of war activities, has not permitted normal development of new methods in astrophysics, and there have been no urgent calls for special instruments.

A grant of $500 made to W. W. Campbell two years ago, to provide the mounting of an ultra-violet spectrograph for use with the Crossley reflecting telescope, was expended, and the finished instrument was described in *Lick. Obs. Bull., Berkeley*, No. 291, in May, 1917. This instrument has been used by Mr. Wright in photographing the spectra of all the brighter planetary nebulae in the northern two-thirds of the sky.

A grant of $300 made in April, 1917, to Professor Joel Stebbins, of the University of Illinois, and a similar grant in like amount made earlier, are being applied, in accordance with agreement, in payment of part-time salary of an assistant to Dr. Stebbins in order to further the latter's development of the photo-electric cell photometer and the application to the study of variable stars. Quoting from Professor Stebbins' report dated April, 1918: "The photo-electric photometer has been improved until it is now from ten to twenty times as sensitive as the selenium photometer. We can measure the brightness of stars three magnitudes fainter than those which it was possible to observe with the selenium instrument. About a dozen new bright variable stars have been discovered, of which eight have been announced at meetings of the American Astronomical Society. We are also carrying on studies of several known variables." In further agreement with the terms of the grant, the University of Illinois has arranged to continue the assistant on full time in Professor Stebbins's department after the close of the present academic year.

A report was received from the Committee on the J. Lawrence Smith Fund, signed by E. W. Morley (Chairman), stating that the Fund now has a cash balance of income of $1188.85 and a balance of invested income amounting to $1532.50, recommending grants No. 9 (as announced below, p. 274), and containing the following reports on previous grants:

No. 3, EDMUND O. HOVEY, American Museum of Natural History, New York, received in 1909 a grant of $400 to aid in the study of certain meteorites. The pressure of adminstra-

tive duties has been so severe that the investigation is suspended, at least for a time, and Dr. Hovey proposed to return the grant. The Committee hesitated, but at last accepted the proposal, and the amount of the grant, together with interest, has been repaid, to the Treasurer of the Academy.

No. 4, C. C. TROWBRIDGE, Columbia University, New York, has received from 1909 to 1917, grants amounting to $1400 to aid in the study of meteor trains. The work of the last year has consisted of the further collection of illustrations of meteor trains and the study of spectrum observations. No further grant is sought. A letter from the recipient follows.

Dear Professor Morley:

I beg to submit herewith a brief report relative to the grant made to me from the J. Lawrence Smith Fund for aid in work on the atmosphere of the earth and on the trains of meteors.

The progress for the year 1917 has been as follows: Work has been continued on the collection of illustrations of meteor trains; on the study of meteor train theories, and study of the spectrum observations.

It has been shown that there is good reason to believe that the spectra of trains observed indicate a gas phosphorescence similar to that of 'active' nitrogen (nitrogen in the phosphorescent state) rather than the light from hot metals as believed by the various observers. Further observations of importance have been made on the auroral features of the meteor train zone. This phase of the investigation is bound up with meteor train study for the following reasons:

The meteor train zone and the main aurora are the same; the potential gradient across this zone is probably the cause of the visual effects in both cases. The drift of the atmosphere as shown by drifting trains in the meteor train zone unquestionably has an important bearing on the electric discharges which cause the auroral glow.

Financial Statement

Total funds received to December 31, 1916	$1,153.50
Total expenditures to December 31, 1916	1,020.67
Balance, December 31, 1916 (as per financial statement submitted March 26, 1917)	$132.83
Received from Treas., Nat. Acad. Sciences, March 22, 1917	250.00
Total	$382.83

Expenditures in 1917

January		M. M. King, typewriting	$2.40
February		Science reprints	8.00
March		Exchange on Washington check	.10
March	12	Geo. Merritt, Jr., asst. 23 hours	13.80
April	2	J. Boldtman, photographer	1.50
April	2	Bureau of Supplies, Columbia Univ.	1.20
April	30	J. Boldtman, photographer	3.40
May	1	Geo. Merritt, Jr., assistant	19.60
May	10	Bur. of Supplies, Columbia Univ.	1.60
June	1	Amy E. Davis, assistant	36.00
June	15	Mabel Weil, assistant	62.70
June	18	Printing, New Era Printing Co.	5.89
			$156.19

Cash on hand, December 31, 1917

Balance in Corn Exchange Bank	$149.90
Cash	1.45
Balance in Washington Savings Bank	75.29
	$226.64

Condensed Statement

Total funds received		$1,403.50
Total expenditures to December 31, 1917	$1,176.86	
Balance	226.64	1,403.50

Respectfully yours,

C. C. TROWBRIDGE.

No. 6, S. A. MITCHELL, University of Virginia, University, Virginia, received in 1915 a grant of $500 to aid in securing observations of paths and radiants of meteors, and in computing orbits when the observations are sufficient; further grants of $300 were made in 1916 and 1917. The war lessened the number of observations secured, during 1917, but this lessened number amounted to 4,231, making the whole number of observations about 19,000. An abstract of results for 1917 has been published by Dr. Olivier in a recent number of *Popular Astronomy*.

No. 7, GEORGE P. MERRILL, United States National Museum, received last November a grant of $400 to aid in further study of certain elements in meteorites. Of this grant he has spent $185, and there remains to his credit $215.

A report was received from the Directors of the Wolcott Gibbs Fund, signed by C. L. Jackson (Chairman), stating that during the past year no application was received for a grant from the Fund, and owing to the disorganization of chemical research by the war, it was not thought worth while to try to get applications; that the unexpended income of the Fund amounts to $360.87; and that holders of grants have reported as follows:

Nos. 2 and 5, M. E. HOLMES, of Connecticut College, finds that the exacting duties of her new position will prevent her from continuing her research, and has returned the unexpended balance of the two grants amounting to $86.32.

No. 6, G. P. BAXTER, Harvard University, has spent $194.31 for material and apparatus since the last report. No platinum was bought, as the war had rendered it too expensive. The three researches described in the last report have been finished, and accounts of the results will be published soon. These were (*a*) Electrolytic Deposition in a Mercury Cathode, and the Atomic Weight of Cadmium, with C. H. Wilson. A slight loss was discovered, and corrected experimentally, after which eight determinations gave the atomic weight of cadmium as 112.40. (*b*) Impurities in Silver and Iodine, with L. W. Parsons. In 1 gram of the silver used for atomic weight determinations 0.004 mgm. of gas were found; in the iodine, 0.002 mgm. of gas. Most exacting spectroscopic tests showed no impurities in the silver. These results dispose of the criticisms of P. A. Guye on the Harvard atomic weight determinations. (*c*) The ratio of Arsenic Trioxide to Iodine, with L. A. Youtz. The atomic weight, 74.96, was found for arsenic. In addition a fourth research has been started. (*d*) The Atomic Weight of Mercury, with Matsusuke Kobayashi. All these researches but the last have been stopped by the enlistment of the graduate students in war service.

Nos. 4 and 7, W. D. Harkins, University of Chicago, has bought a vacuum pump for $55.00, and is about to buy one still more efficient. He has studied the "Secondary Valence

and Werner's Co-ordination Number from the Standpoint of the Ammines of Cobalt" with G. L. Clark. The existence of the salt $CoCl_3ION H_3$ has been established; and the phenomena observed in the formation of this compound have been studied, and some of its physical constants. The work was broken off by the enlistment of Mr. Clark in the service of the Government before it could be brought to an end. It will be continued as soon as possible, as it promises to show either that Werner's constitution of the cobaltammines is incorrect, or that his co-ordination number must be changed from 6 to 10. Other results of great interest are also indicated.

No. 8, R. L. Datta, Presidency College, Calcutta, has sent orders for organic chemicals amounting to £20, but has received none because of the war.

A report was received from the Committee on the Marsh Fund, signed by E. H. Moore, Chairman, recommending grant No. 2 (as announced below, p. 274) and containing the following statement:

No. 1, J. M. Clarke, State Museum, Albany, reports progress in the assembling of material for his study of mutualism, symbiosis, and dependent life among animals.

A report was received from the Committee on the Murray Fund, signed by Wm. H. Dall, Chairman, as follows:

On November 1, the sum to the credit of the Murray Fund was $569.61. The Treasurer suggested and as Chairman I approved of the investment of the major part of this sum in Liberty bonds, which (should the Council decide to offer the medal this year) could readily be turned into cash. . . . .

A report was received from the Committee on the Comstock Fund, signed by Edw. L. Nichols, Chairman, as follows:

Five years having nearly elapsed since the first award of the Comstock prize to Professor (now Lieutenant Colonel) R. A. Millikan, the committee met in Philadelphia at the time of the November (1917) sessions of the Academy, four members being present. After careful consideration of various suggestions previously made in writing at the request of the chairman, the committee unanimously recommended that the second award of the Comstock Prize be made by the Academy to Samuel Jackson Barnett, Professor of Physics at Ohio State University, for his investigations on Magnetization by Rotation.

In this research the following fundamental and very important facts were established:

(1) that there are within the iron currents of negative electricity in orbital revolution,

(2) that these gyrostatic systems have inertia and are capable of definite orientation or arrangement by the rotation of the body without the action of any external magnetic field,

(3) that such orientation manifests itself as a magnetization of the body as a whole.

The committee further recommended that as in the case of the first award, the value of the prize be $1,500.00.

The President presented recommendations from the Committees on the Henry Draper Medal and the Daniel Giraud Elliot Medal and Honorarium for the following awards which were approved by the Academy:

American Museum of Natural History,
New York, February 7, 1918.

My dear Mr. Day:

Thanking you for your letter of February sixth and the return of my letter of January ninth, as Chairman of the Committee on the award of the Daniel Giraud Elliot Gold Medal, I

believe that the committee will agree that Dr. Frank M. Chapman, of the American Museum of Natural History, in view of his memoir, "The Distribution of Bird-life in Colombia, a contribution to a biological survey of South America," *Bulletin of the American Museum of Natural History*, Volume XXXVI, 1917, pages 7–10 (Roman), 1–729 (Arabic), is entitled to first consideration and premiership for the year 1917, as having produced the most earnest single work in zoölogy, the result of six years serious exploration and research, namely, from December, 1910, until the publication of the volume in December, 1917.

As chairman of the committee, I respectfully submit this as a substitute report, with the approval of my colleagues.

Fortunately, Doctor Chapman is one of the most distinguished of the many followers of Dr. Joel Asaph Allen, and he was also closely associated with Dr. Daniel Giraud Elliot; consequently I trust the Committee will regard the award of the medal as eminently appropriate.

Respectfully submitted,

HENRY FAIRFIELD OSBORN, *Chairman.*

Mount Hamilton, January 19, 1918.

Dear Dr. Day:

I have just sent you the following night letter:

> "I herewith certify nomination of Walter S. Adams, Mount Wilson Observatory, for his investigations in astrophysics, by Draper Committee for award of Draper Gold Medal. I hope Council can make award practicable at this year's meeting."

Dr. Walter Sidney Adams has discovered and developed a method of determining the distances of the stars, by means of the spectrograph, which the Henry Draper Committee believes is one of the great advances in modern Astronomy. Like most methods of high value, its fundamentals are exceedingly simple. The basic fact is that certain lines are enhanced in the spectra of stars of high absolute luminosity, and certain other lines are enhanced in the spectra of stars of low absolute luminosity; in other words, the intensities of certain lines increase continuously with increasing absolute luminosities, and the intensities of certain other linds increase continuously with decreasing absolute luminosities. The approximate distances of a few hundred of the nearer stars, measured by the older methods, are known. These distances enable us to compute the absolute magnitudes or luminosities of those stars. The correlation of these absolute magnitudes and the estimated relative intensities of the critical lines in their spectra have given Mr. Adams the power to determine the functional relations connecting these elements, and thus to determine the absolute magnitudes of stars not yet observed for distance. Knowing the magnitude of a star as observed from the earth, and the absolute magnitude of the same star as determined by the spectrograph, the solution of a simple equation yields at once the value of the star's distance. Here is a powerful means of extending the list of stars whose distances are known, and the Committee confidently expects that the method will be applied successfully to thousands of stars which are too distant for successful attack by the earlier methods. The method should in due time tell us much concerning the linear scale of the nearer parts of our stellar system. The secondary applications of the method to astronomical problems are likewise of great promise.

Mr. Adams has applied the spectrographic method to the determination of the distances of more than five hundred stars, of the Harvard spectral classes F to Mb inclusive, and a comparison of his results with those obtained by the older methods, as to rapidity and accuracy, is a subject for congratulation.

The method has not yet been applied satisfactorily to stars of certain spectral classes, but it is hoped that the dependence of such spectra upon absolute luminosities or other elements may be found in the near future.

Dr. Adams's contributions to other lines of astronomical research have been many, extensive and fruitful. We mention three:

The spectrographic determination of the sun's rotational speeds by comparing the motions of approach of the eastern limb and the motions of recession of the western limb with the apparent motions of approach or recession of points on the solar meridian passing through the earth. The results form a monumental contribution to the complicated and still unsolved problem of the solar rotation.

His long exposures on the spectra of the present-day faint remnants of new stars formerly brilliant have shown that these stars are now of the Wolf-Rayet type.

The more thorough application of high dispersion spectroscopy to the study of the sun's chromosphere. Prior to the establishment of the Mount Wilson Solar Observatory, this was essentially a total solar eclipse problem. Stratification of the chromosphere has been studied by Adams without an eclipse at least as successfully as it had formerly been studied at times of total solar eclipse.

Respectfully submitted,

W. W. CAMPBELL, *Chairman.*

GENERAL BUSINESS

The following report from the Editorial Board of the PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES was presented by the Chairman, Raymond Pearl:

1. Three volumes of the PROCEEDINGS have been completed, and four numbers of the fourth volume have been issued.

The statistics as to the make-up of the third volume, both in respect of subject matter and of source of the contributions, have been printed in the Annual Report of the Academy for 1917, and need not now be repeated except so far as covers one point.

The statistics of articles by members of the Academy as compared with articles by non-members are interesting mainly in showing a progressive diminution in the percentage of articles by members, despite the increase in membership of the Academy. If there are obstacles which can be removed and which hinder members of the Academy from printing in the PROCEEDINGS, would it not be well to make efforts to remove them? The Academy represents the highest point in American research, and if the PROCEEDINGS should actually contain articles representing the totality of the investigations of members of the Academy it would become thereby largely representative of all American research and of very high grade, and furthermore it would be more truly the Proceedings of the Academy in the sense that corresponding publications of foreign academies are representative of their research.

2. At the Autumn meeting the terms of office of five members of the Editorial Board expired, and new appointments were made by the Council as follows: Jacques Loeb, W. M. Wheeler, E. B. Frost, E. L. Thorndike, and E. H. Moore.

3. At the Autumn meeting the Board decided to put into operation certain changes in the typographical make-up of the PROCEEDINGS in the interest of economy. These changes have been made with satisfactory results.

4. The Editorial Board is of the opinion that in view of the now established and recognized position of the PROCEEDINGS as a medium of scientific publication, the members of the Academy might well contribute more of their own papers to its pages than they now do, both from the standpoint of self-interest as well as from a sense of duty to the Academy and what it stands for. In this connection the Board would recommend that the Academy adopt as a general principle the policy of requiring each recipient of a grant for research from any of its special funds to publish some account of the results of the researches under the grant in the PROCEEDINGS.

5. If the above recommendation is adopted, the Board would further recommend that the Academy suggest to the several committees having in charge trust funds from which grants are made that whenever accounts of researches under grants are published in the PROCEED-

INGS there shall be paid over from the Trust Funds out of which the grants are made, to the PROCEEDINGS account, if such action be permissible under the terms of the bequest, a sum of money to cover the expense of the publication at a rate of $6.00 per printed page.

Anent the above report the following recommendations were submitted from the Council and adopted·

That the following recommendations from the Editorial Board of the PROCEEDINGS be approved by the Academy and that the Home Secretary be instructed to bring these recomdations to the attention of the members of the Academy and the chairmen of the trust funds.

That members of the Academy be requested to contribute their own papers to the PROCEEDINGS.

That the policy of requiring each recipient of a grant for any research from any of the special funds to publish an account of the results of the researches under the grant in the PROCEEDINGS be approved.

That the Academy request the committees and trustees of the several trust funds of the Academy from which grants are made that whenever accounts of researches under grants are published in the PROCEEDINGS there shall be paid over from the Trust Fund out of which the grants are made, to the PROCEEDINGS account, if such action is permissible under the terms of the bequest, a sum of money to cover the expense of the publication.

A report was received from the Finance Committee of the PROCEEDINGS, signed by C. B. Davenport, Chairman, F. R. Lillie, and Raymond Pearl, as follows:

The estimated net cost of the PROCEEDINGS for 1918 is $5,600.00.

The estimated income is as follows:

From subscriptions (provided each member of the Academy becomes responsible for one subscription)	$1,800.00
One-third guarantee fund of $2,500	833.00
Estimated income of Billings Fund	187.00
Sundry other income (members dues, $850, N.R.C., $400, Dr. Walcott, special, $100)	1,350.00
Total estimated income	$4,170.00
Total estimated deficit	$1,430.00

If recommendation of the Editorial Board that space for reports of special grants in PROCEEDINGS be specially paid for be adopted, this deficit will be reduced to $1,200.00.

The Committee plans to raise funds to meet this deficit.

A report was received from the Auditing Committee, signed by C. G. Abbot, Chairman, W. F. Durand, and A. L. Day, certifying the accuracy of the Treasurer's books.

The Chairman of the Research Council, Mr. Hale, presented a verbal report in which he called attention to the printed report of the Research Council which had appeared in the Annual Report of the National Academy of Sciences.

The following amendment to the Constitution was presented from the Committee of the Whole and adopted:

That the constitution be amended by substituting in Article II, Section 1, line 3 (Report, 1916) the word *four* for the word *six* so that it will read for a term of four years . . . .

to take effect on the expiration of the term of office of the present incumbents or in case of a vacancy.

Article II, Section 1, when amended to read:

SECTION 1. The officers of the academy shall be a president, a vice president, a foreign secretary, a home secretary, and a treasurer, all of whom shall be elected for a term of four years, by a majority of votes present, at the first stated meeting after the expiration of the current terms, provided that existing officers retain their places until their successors are elected. In case of a vacancy, the election for four years shall be held in the same manner at the meeting when such vacancy occurs, or at the next stated meeting thereafter, as the academy may direct. A vacancy in the office of treasurer or home secretary may, however, be filled by appointment of the president of the academy until the next stated meeting of the academy.

The President, in closing, gave the present status of the aeronautical work that is being carried on by the Academy for the country.

ELECTION OF OFFICERS AND MEMBERS

Two Members of the Council.—W. H. HOWELL to succeed himself, term expiring in 1921; C. G. ABBOT to succeed John M. Coulter, term expiring in 1921.

The following persons were elected as new members of the Academy.

ROBERT GRANT AITKEN, Astronomer, Lick Observatory, California.
GEORGE FRANCIS ATKINSON, Botanist, Cornell University, Ithaca, New York.
GEORGE DAVID BIRKHOFF, Mathematician, Harvard University, Cambridge, Mass.
PERCY WILLIAMS BRIDGMAN, Physicist, Harvard University, Cambridge, Mass.
STEPHEN ALFRED FORBES, Zoölogist, Urbana, Illinois.
JOHN RIPLEY FREEMAN, Engineer, Providence, Rhode Island.
CHARLES JUDSON HERRICK, Neurologist, University of Chicago, Chicago, Illinois.
LUDVIG HEKTOEN, Pathologist, University of Chicago, Chicago, Illinois.
FRANK BALDWIN JEWETT, Engineer, Western Electric Company, New York, New York.
WALTER JONES, Physiologist, Johns Hopkins University, Baltimore, Maryland.
IRVING LANGMUIR, Chemist, General Electric Company, Schenectady, New York.
CHARLES ELWOOD MENDENHALL, Physicist, University of Wisconsin, Madison, Wisconsin.
JOHN CAMPBELL MERRIAM, Paleontologist, University of California, Berkeley, California.
HENRY NORRIS RUSSELL, Astronomer, Princeton University. Princeton, New Jersey.
DAVID WATSON TAYLOR, Engineer, Admiral and Chief of the Bureau of Construction and Repair, United States Navy.

SCIENTIFIC SESSIONS

Two public lectures on the WILLIAM ELLERY HALE Foundation were given on April 22 and 23 by JOHN C. MERRIAM, of the University of California, on the Beginnings of Human History from the Geologic Record.

Four public scientific sessions were held on April 22 and 23 at which the following papers were presented:

FRANCIS G. BENEDICT: The effects of a prolonged reduced diet on twenty-five college men: I. On basal metabolism and nitrogen excretion.

WALTER R. MILES (introduced by F. G. Benedict): The effects of a prolonged reduced diet on twenty-five college men: II. On neuromuscular processes and mental condition (illustrated).

H. MONMOUTH SMITH (introduced by F. G. Benedict): The effects of a prolonged reduced diet on twenty-five college men: III. On efficiency during muscular work and general muscular condition (motion pictures).

W. S. HALSTED: The partial occlusion of great arteries in man and animals (illustrated).

S. J. MELTZER: Three papers (illustrated). (*a*) The favorable effect of subcutaneous injection of magnesium sulphate in tetanus. (*b*) The possible danger of intravenous injection of magnesium sulphate. (*c*) The antagonistic and curative action of calcium salts in these cases.

HENRY FAIRFIELD OSBORN: The Liberty field hospital ward. Designed on the unit construction plan. Portable. Adapted to American overseas summer and winter service (motion pictures).

SIMON FLEXNER: The war and medical research (illustrated).

EDWARD KASNER: Conformal geometry.

S. J. BARNETT (by invitation. Comstock prize recipient): Magnetism by rotation.

A. A. MICHELSON: On the correction of optical surfaces.

W. W. CAMPBELL: Some recent observations of the brighter nebulae (illustrated).

R. A. MILLIKAN: Physical researches for the war.

F. W. CLARKE: Notes on isotopic lead.

LAWRENCE J. HENDERSON (introduced by Raymond Pearl): The physico-chemical properties of gluten.

THOMAS WAYLAND VAUGHAN (introduced by David White): Correlation of the tertiary formations of the southeastern United States, Central America and the West Indies.

W. M. DAVIS: Coast survey charts and fringing reefs of the Philippine Islands (illustrated).

HENRY FAIRFIELD OSBORN and WILLIAM K. GREGORY: Recent researches on the skeletal adaptations and modes of locomotion of the Sauropod Dinosaurs (illustrated).

CHARLES D. WALCOTT: Some additional data on the Cambrian Trilobites (illustrated).

C. R. VAN HISE: The development of Governmental regulations during the world war.

C. HART MERRIAM: The big bears of North America.

G. H. PARKER: The growth of the Pribilof fur-seal herd between 1912 and 1917 (illustrated).

HENRY H. DONALDSON: A comparison of the growth changes in the nervous system of the rat with the corresponding changes in man (illustrated).

ROBERT M. YERKES (by invitation): Measuring the mental strength of an army (illustrated).

ARTHUR GORDON WEBSTER: Some considerations on the exterior ballistics of a gun of 75 miles range.

J. P. IDDINGS: Biographical memoir of the late Arnold Hague.

C. G. ABBOT: Perodicity in the variation of the sun.

JOHN M. CLARKE: Biographical memoir of the late William Bullock Clark.

EDWIN H. HALL: Ionization in solid metals.

E. L. NICHOLS and H. L. HOWES: On the types of decay of phosphorescence.

AWARD OF MEDALS

The following medals were awarded at the annual dinner on the evening of April 23, 1918, at the Cosmos Club:

The Comstock Prize of $1500.00, to Samuel Jackson Barnett, of Ohio State University, for his investigations in magnetization by rotation.

The Henry Draper Medal, to Walter S. Adams, of the Mt. Wilson Solar Observatory, California, for his investigations in astrophysics.

The Daniel Giraud Elliot Gold Medal and Honorarium, to Frank M. Chapman, of the American Museum of Natural History, for his memoir, "The Distribution of Bird Life in Colombia, A Contribution to a Biological Survey of South America," *Bulletin of the American Museum of Natural History*, **36**, 1917, (vii–x, 1–729).

RESEARCH GRANTS FROM TRUST FUNDS OF THE ACADEMY

During the twelve months preceding the Annual Meeting of the Academy the following grants for the promotion of research were made from the Trust Funds of the Academy.

GRANTS FROM THE BACHE FUND

No. 205, T. H. GOODSPEED, University of California, $100. For studies of inheritance in Nicotiana hybrids.

No. 206, REGINALD A. DALY, Harvard University, $700. For the completion of the deep sea thermograph designed and partly constructed under Grant No. 194. In continuation of No. 194.

No. 207, T. H. GRONWALL, New York City, $300. To complete and extend mathematical researches on conformal representation.

No. 208, A. FRANKLIN SHULL, University of Michigan, $400. To investigate the cause of sex production and the life cycle of rotifers, together with artificial modification of life cycle; differential factors in fertilization of male-producing and female-producing rotifers; sex determination and the life cycle of the thrips; cause of sex production, wing production, and other cyclical phenomena in aphids.

No. 209, CECIL K. DRINKER, Harvard Medical School, $350. For the closer study of the factors involved in extension of unchecked red cells and leucocytes in the dog.

GRANTS FROM THE WATSON FUND

No. 16, HERBERT C. WILSON, Goodsell Observatory, $300. For a continuance of the work of the determination of the position and brightness of asteroids (chiefly those discovered by Watson) by the photographic method, together with a study of the brightness of some variable stars. (Supplementary to Grant No. 15).

No. 17, JOHN A. MILLER, Sproul Observatory, $500. To measure plates for determining stellar parallaxes (Supplementary to Grant No. 14).

GRANTS FROM THE J. LAWRENCE SMITH FUND

No. 9. S. A. Mitchell, University of Virginia, $300. To continue his researches on the paths, radiants, and orbits of meteors. (Supplementary to Grant No. 8.)

GRANT FROM THE MARSH FUND

No. 2, M. FERDINAND CANU, Versailles, France, $250. For investigations in cooperation with Dr. R. S. Bassler, of the United States National Museum, of the early tertiary bryozoa of North America.